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March 1969

HANDBOOK OF SELECTED PROPERTIES
OF AIR-AND WATER-REACTIVE MATERIALS

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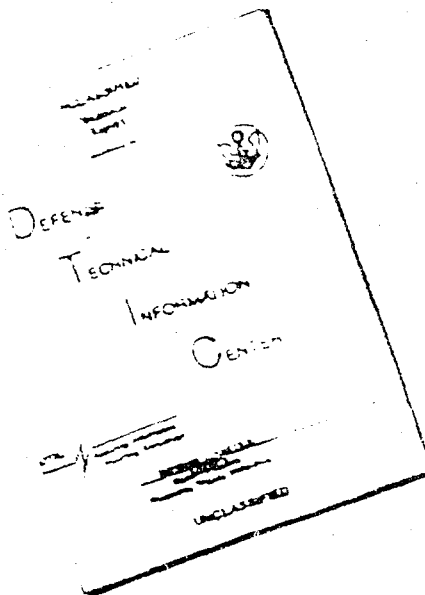


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by

Jack R. Gibson
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This report was reviewed for adequacy and technical accuracy
by William Ripley

Released

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Concept Development Division
Research and Development Department

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UNCLASSIFIED

**HANDBOOK OF SELECTED
PROPERTIES OF AIR- AND WATER
REACTIVE MATERIALS**

**Final Report
January 1966 - December 1968**

**Jack R. Gibson
Joanna D. Weber**

Prepared Under Contract PO-C-0024 for the Research and Development Department, U. S. Naval Ammunition Depot, Crane, Indiana, 47522, by the Special Bibliographies Section, Science and Technology Division, Library of Congress, Washington, D. C. 20540.

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ABSTRACT

The Handbook of Selected Properties of Air-Reactive and Water-Reactive Materials represents the work resulting from the literature search covering the years 1930 through 1968. Data are presented on the following properties of the pertinent compounds: molecular weight, melting point, characteristics, boiling point, vapor pressure, synthesis, solubility, thermodynamic properties and flammability. In addition, attention is paid to other characteristics such as toxicity, handling and military and industrial uses.

The material is arranged in three parts: Part I. Inorganic Compounds, Part II. Organic Compounds, and Part III. Miscellaneous Compounds (analyzing complex compounds, mixtures and byproducts of chemical reactions).

FOREWORD

The Handbook of Selected Properties of Air-Reactive and Water-Reactive Materials was prepared under Contract PO-6-0024 by the Special Bibliographies Section, Science and Technology Division, Library of Congress.

Scope

The task consisted of searching both the open literature and unclassified reports (covering the period 1950 through 1968) for data on the properties of the pertinent compounds. The information derived from the references identified is indicated in the form of data and annotations to the individual properties.

The majority of compounds analyzed are spontaneously flammable in air, many are explosive with air and/or water. The remaining compounds are spontaneously flammable in air and water or produce smoke, and a few fit no definite category (they are spontaneously flammable only under certain circumstances or yield a spontaneously flammable compound in contact with air and/or water).

Sources Searched

In addition to the catalogs in the Library of Congress, among the important sources to the literature searched were:

Applied Science and Technology Index
ASM Review of Metal Literature
Bibliography of Chemical Reviews
Chemical Abstracts Decennial Index
Chemical Abstracts Subject Indexes
Engineering Index
Nuclear Science Abstracts
Technical Translations
U. S. Government Research Reports

Entries in the Bibliography are listed in an alpha-numeric order. No specific page indication is given for an entry cited in more than ten separate references throughout the Handbook.

Arrangement

The information on the properties of the compounds is presented alphabetically by chemical symbols on data sheets arranged in three parts:

- I. Inorganic compounds
- II. Organic compounds
- III. Miscellaneous compounds

The first two parts are further subdivided into groups of compounds. Data sheets on compounds in Part 3 are randomly arranged because of their varied chemical composition.

Attempts have been made to collect information on as many properties of the pertinent compounds as possible. These properties may range from physical and chemical characteristics through manufacturing and handling to military and industrial uses of a given compound.

Acknowledgments

The compilation of the Handbook was supervised by Dr. Clement R. Brown, Head, Special Bibliographies Section through December 1967. Bibliographic guidance was supplied by Dr. Madeleine J. Wilkins, Assistant Head, Special Bibliographies Section. Special note of appreciation is due to Mrs. Beatrice T. Trease for her invaluable contribution in preparing the Handbook for publication.

I. INORGANIC COMPOUNDS

(a) ELEMENTS

SILVER

Mol. Wt.:
107.87

Formula:
Ag

M.P.:
960.8°C (79)

Characteristic:
Solid - white cubic metal (79)

V.P.:
101575 (79)

d./sp. gr.:
10.5²⁰ (79)

B.P.:
1950°C (79)

$\frac{n_D}{d_D}$:
.54 (79)

Synthesis

Prepare ultrafine powder by vacuum (less than 500 microns) evaporation and condensation (148).

Solubility:

1. alkaline solvents, hot and cold H₂O; s. HNO₃, hot H₂SO₄, KCN (79).

Flammability:

Fine powder spontaneously flammable (148).

ALUMINUM

Mol. Wt.:
26.9815 (79)

Formula:
Al

M.P.:
659.7°C (79)

Characteristic:
Solid - silver colored powder,
metallic, ductile (79)

d./sp. gr.:
2.702 g/cm³ (195)

B.P.:
2056°C (195)

V.P.:
1284 (195)

Toxicity:

Low, possible cause of pulmonary fibrosis (195).

Synthesis

From purified and calcined Al₂O₃ (obtained from bauxite). It is dissolved in molten cryolite (2AlF₃·6NaF·3CaF₂) with calcium fluoride, it is kept fused by passing an electric arc between carbon electrodes, the dissolved alumina is decomposed by the electric current into aluminum and oxygen (214).

Ignition temperature:

(80% pass through 270 mesh): 645°C (224).

Solubility:

1. cold and hot H₂O, concentrated HNO₃, hot CH₃COOH; s. alkaline solvents, HCl, H₂SO₄ (79).

Handling:

Keep aluminum powder dry, do not permit dust to filter into air, keep containers closed, do not pour from one container to another (228).

Thermodynamic properties:

heat of formation (sol): 0
heat of formation (liq): 55 kcal/mol
surface tensions 520 dynes/cm (at 750°C)
heat of fusion: 2550 cal/g atom (at 660°C)
heat of sublimation: 67497 cal/g atom (at 298.1°K)
heat of vaporization: 65084 cal/g atom (at 298.1K)
heat capacity: 5.8 cal/°K (17)
thermal conductivity: 117 Btu/hr/ft²/(deg F/ft) (17)

Military and industrial uses:

Used as pigment, aluminum based ink for printing (214).

Flammability:

Dust may explode in air, wet aluminum powder may ignite spontaneously in air (228).

BORON

Mol. Wt.:

10.811

Formula:

B

M.P.:

2300°C (179)

Characteristics:

Solid - monoclinic crystals, yellow
or brown amorphous powder (79)

d./sp. gr.:

2.34 (79)

B.P.:

2550°C (79)

Synthesis:

(1) Electrolysis of fused bath of KCl or KF and Potassium fluoroborate and boric oxide; (2) Heat boric oxides with powdered Magnesium; (3) Reduce boron halides with gas dispersion of molten alkali metal (190).

Unique conditions, reaction products:

Boron burns spontaneously in chlorine gas, ignites with heat in nitrous oxide, incandescent with fluorine, iodic acid, concentrated HNO₃, or nitroethyl fluoride (143).

Solubility:

l. cold and hot H₂O; v. sl. s. HNO₃ (79)

Thermodynamic properties:

Heat of combustion: 140 kcal/mol (199)

Military and industrial uses:

In nuclear chemistry as neutron absorber, in ignition rectifiers, and in alloys to harden other metals (132).

Flammability:

Dust ignites in air (79).

BARIUM

Mol. Wt.:

137.34

Formula:

Ba

M.P.:

850°C (79)

Characteristics:

Solid-yellow silver metal (195)

d./sp. gr.:

3.5120 (79)

B.P.:

1527°C (79)

1140°C (195)

V.P.:

10⁻¹⁰ mm (195)

Synthesis:

(1) $3\text{BaO} + 2\text{Al} \rightarrow 3\text{Ba} + \text{Al}_2\text{O}_3$ (repeat distillation in high vacuum) (80)

(2) $\text{Ba}(\text{N}_3)_2 \rightarrow \text{Ba} + 3\text{N}_2$ (decomposition) (80)

Solubility:

d. with evolution of H_2 in H_2O ; s. alcohol; l. C_6H_6 (79)

Military and industrial uses:

Used in alloys and pyrotechnics (190).

Flammability:

Spontaneously flammable in moist air (43).

BERYLLIUM

Mol. Wt.:

9.01

Formula:

Be

M.P.:

1278 ± 5°C (79)

Characteristics:

Solid - gray, metal, hexagonal (79)

d./sp. gr.:

1.34820 (79)

B.P.:

2970-2960 (79)

Toxicity:

Extremely toxic respiratory poison and eye irritant; threshold limit value .002 mg/m³ (142).

Synthesis:

Ultrafine powder prepared by vacuum (less than 500 microns) evaporation and condensation (148).

Unique conditions, reaction products:

Beryllium with phosphorus vapors is incandescent (143).

Solubility:

l. cold H_2O , Hg; s. dilute acid, alkaline solvent; sl. s. with d. hot H_2O (79).

Handling:

Protect from physical damage; keep dry; isolate from acids, caustics and chlorinated hydrocarbons; separate from oxidizing materials (142).

Flammability:

Powder spontaneously flammable (148).

BISMUTH

Mol. Wt.:

209.00

Formulas:

Bi

M.P.:

271.3°C (195)

Characteristics:

Solid - red, hard, brittle (214)

d./sp. gr.:

9.80 (195)

B.P.:

1420-1560°C (195)

V.P.:

11021 (195)

Synthesis:

Formed from decomposition of bismuth citrate in vacuo at 350°C (77).

Unique conditions, reaction products:

Powdered bismuth burns spontaneously in gaseous chlorine; ignites at 80°C with liquid chlorine; becomes red hot with fuming HNO_3 (143).

Flammability:

Spontaneously flammable (77).

CHARCOAL
(Freshly calcined)

Mol. Wt.:

12.0

Formulas:

C & impurities

M.P.:

>3500°C (195)

B.P.:

4200°C (195)

d./sp. gr.:

3.51 (195)

Toxicity:

Nil, except slight on inhalation (195).

Military and industrial uses:

Decolorization, filtration, metallurgical absorbent, and arc light electrode (190)

Flammability:

Spontaneously flammable in air when freshly calcined (79).

CALCIUM

Mol. Wt.:

40.08

Formula:

Ca

M.P.:

848 ± .5°C (79)

B.P.:

1240°C (79)

V.P.:
10⁹⁸³ (195)

d. /sp. gr.:

1.54 (79)

Toxicity:

Fumes from burning calcium irritating to skin, eye and mucous membranes (195).

Synthesis:

(1) electrolysis of fused CaCl₂

(2) reduction of lime with aluminum ($3\text{CaO} + 2\text{Al} \rightarrow \text{Al}_2\text{O}_3 + 3\text{Ca}$)

(3) reduction of lime with silicon ($8\text{CaO} + 2\text{Si} \rightarrow (2\text{CaO} \cdot \text{SiO}_2) + 4\text{Ca}$)

} (132)

Unique conditions, reaction products:

Yields hydrogen on contact with H₂O (195).

Solubility:

d. in H₂O to yield H₂ + Ca(OH)₂; s. acids, liquid NH₃; sl. s. alcohol; i. C₆H₆ (79)

Handling:

Store under kerosene or benzene (132); protect from physical damage, keep from water, avoid high temperatures (142).

Thermodynamic properties:

Heat of combustion: 151.7 kcal/mol (132).

Military and industrial uses:

Deoxidizer for copper, beryllium and steel; used to harden lead for bearings; used with cerium in flints (132).

Flammability:

Spontaneously flammable in air when finely divided (132).

CADMIUM

Mol. Wt.:

112.40

Formula:

Cd

M.P.:
320.9°C (79)

B.P.:
767±2°C (79)

V.P.:
1394 (195)

d./sp. gr.:
8.642 (79)

n_D:
.82 (liq) (79)
1.13 (sol) (79)

Toxicity:

On ingestion causes salivation, choking, vomiting, diarrhea, and tenesmus (132).

Synthesis:

Decompose cadmium tartrate over aluminum burner, heat dried crystal tartrates until gas generation ceases, pyrophoric cadmium residue remains (76).

Unique conditions, reaction products:

Heat pyrophoric residue to 500°-600°C loses pyrophoricity (76).

Solubility:

i. hot and cold H₂O; s. acid, NH₄NO₃, hot H₂SO₄ (79)

Thermodynamic properties:

latent heat of fusion: 13.2 cal/g	} (121)
latent heat of vaporization: 286.4 cal/g	
electrical resistivity: 34.12 μ ohms (at 500°C)	
surface tension: 598 dynes/cm (at 420°C)	

Military and industrial uses:

Used for electroplating (214).

Flammability:

Spontaneously flammable (76).

CERIUM

Mol. Wt.:
140.12

Formulas:
Ce

M.P.:
815°C (79)
640°C (195)

Characteristics:
Solid - steel gray crystal,
cubic or hexagonal (195)

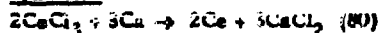
d./sp. gr.:
6.78 (79)

B.P.:
2417°C (79)
1400°C (195)

Toxicity:

Nil, except very low on ingestion and inhalation (195).

Synthesis



Solubility

sl. d. cold H_2O ; d. hot H_2O ; s. dilute acid; l. alkaline solvent (79)

Military and industrial uses

Used in magnesium and aluminum alloys to improve mechanical properties, certain types of glass, ferro alloys for films and pyrotechnics (58).

Flammability

Spontaneously flammable in air at $150^\circ\text{--}180^\circ\text{C}$ (195).

COBALT

Mol. wt.:

58.933

Formulas

Co

M.P.:

1495°C (79)

Characteristics

Solid - silver gray, metallic
cubic (79)

d./sp. gr.:

8.9 (79)

B.P.:

2900°C (195)

3550°C (79)

Toxicity

Low by oral ingestion; powder can produce dermatitis (56).

Synthesis

- (1) $2\text{CoO}(\text{OH}) + 3\text{H}_2 \rightarrow 2\text{Co} + 4\text{H}_2\text{O}$ (reduce cobalt (III) hydroxide in porcelain boat and reduce in stream of hydrogen) (80)
- (2) Add 200 ml 20% NaOH to $\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ in 300 ml H_2O , redissolve the precipitate and add a 500 ml H_2O solution of 29.1g $\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ and 20 ml concentrated HNO_3 ; settle, wash with H_2O , centrifuge, and dry the violet rose precipitate; grind under H_2O and boil until nitrate is absent, centrifuge and dry (80).

Unique conditions, reaction products

Incandescent with acetylene (143).

Solubility

l. cold and hot H_2O ; s. acids (79)

Military and industrial uses

Used in: Cobalt plating, carbide type alloys, and a bonding material for cemented Tungsten carbides (58).

Flammability

Spontaneously flammable (80).

CHROMIUM

Mol. Wt.:
51.996

Formulas:
Cr

M.P.:
1930±10°C (79)

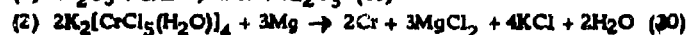
Characteristics:
Solid - steel gray, cubic,
very hard (79)

d./sp. gr.:
7.2028 (79)

B.P.:
2480°C (79)

V.P.:
11616 (79)

Synthesis



Unique conditions, reaction products

Incandescent with nitric oxide (143); vivid incandescence with fused potassium chlorate (143);
vivid incandescence with sulfur dioxide (43).

Solubility:

i. hot and cold H_2O , HNO_3 , aqua regia; s. dilute H_2SO_4 , HCl (79)

Flammability:

Spontaneously flammable (240).

CESIUM

Mol. Wt.:
132.905

Formulas:
Cs

M.P.:
28.6°C (79)

Characteristics:
Solid - silver metallic hexagonal
crystal (79)

d./sp. gr.:
1.878515 (179)

B.P.:
678±5°C (79)

V.P.:
1279 (195)

Toxicity:

Pronounced physiological action, can cause hyperirritability with spasms, can cause death in animals
when in the same proportion as potassium content of diet (195).

Synthesis



Unique conditions, reaction products

Combines vigorously with halides at room temperature (30); with H_2O or steam yields heat and hydro-
gen (195); possible vigorous reaction with oxidizing material (195).

Solubility

d. cold H_2O ; s. liquid NH_3 (79)

Thermodynamic properties

conductivity of liquids 10.65 Btu/hr ft²F (216)
conductivity of vapor .0033 Btu/hr ft²F (216)
latent heat of fusion 6.907 Btu/lb (216)
latent heat of vaporization 211.2 Btu/lb (216)
Resistivity 14.36 μ ohm/in. (216)
ionization potential 3.893 volts (216)
heat of formation 19.9 kcal/mol (90)
specific heat (liq) .0572 Btu/lb²F (216)
specific heat (vap) .0372 Btu/lb²F (216)

Military and industrial uses

Sensitive elements in photocells, radio tubes, and ion propulsion systems (190).

Flammability

Spontaneously flammable in moist air (195); spontaneously flammable in air at room temperature if surface is clean (143); spontaneously flammable in dry oxygen (143); at 20°C heat of reaction with water sufficient to ignite hydrogen released (143).

COPPER

Mol. Wt.:

63.54

Formula:

Cu

M. P.:

1083°C (79)

Characteristics

Solid - red metal, cubic (79)

d./sp. gr.:

8.92 (79)

B. Pt.

2595°C (79)
2324°C (195)

V. P.:

11628 (195)

Synthesis

(1) decompose copper citrate in vacuo at 350°-450°C (77); (2) vacuum (500 microns) evaporation and condensation (148); (3) from sulfide ores, concentrate roasting and forming matte - reduce the matte to crude or blister copper and reduce electrolytically (77).

Unique conditions, reaction products

Copper foil spontaneously ignites in gaseous chlorine (143).

Solubility

l. hot and cold H_2O ; s. HNO_3 , hot H_2SO_4 ; v. sl. s. HCl , NH_4OH (79).

Military and industrial uses

Good conductor of heat and electricity, used for alloying with other metals (77).

Flammability

Fine powders spontaneously flammable (148).

DEUTERIUM

Mol. Wt.:
4.032

Formula:
 D_2

Synonyms:
Heavy hydrogen

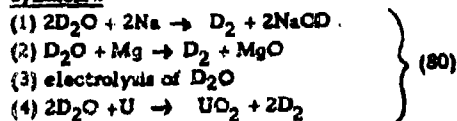
M.P.:
-254.6121 (79)

Characteristics:
Gas - colorless (79)

d./sp. gr.:
2 (79)

B.P.:
-249.7°C (79)

Synthesis



Solubility:

sl. s. cold H_2O (79)

Thermodynamic properties:

heat of fusion: 47 cal/g (132)

heat of evaporation: (at 195 mm) 302.3 cal/g (132)

Flammability:

Spontaneously flammable (27)

EUROPIUM

Mol. Wt.:
151.96

Formula:
Eu

M.P.:
 $1150 \pm 50^\circ C$ (79)

Characteristics:
Solid - steel gray metal (79)

d./sp. gr.:
5.244 (79)

Synthesis

Reduce the oxide with lanthium or misch metal (190).

Unique conditions, reaction products

With H_2O liberates hydrogen (190)

Solubility:

l. hot and cold H_2O (78)

Flammability:

Oxidizes rapidly in air and may burn spontaneously (190)

IRON

Mol. Wt.:

55.847

Formulas:

Fe

Synonyms:

Ferrum

M.P.:

1535°C (195)

Characteristics:

Solid - silver cubic metal (79)

d./sp. gr.:

7.86 (79)

B.P.:

3000°C (195)

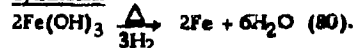
V.P.:

11787 (195)

Toxicity:

Nil, except very low on inhalation; threshold limit 15 mg/m³ as oxide; iron dust can cause conjunctivitis, chorioiditis and/or retinitis. Iron ore dust can cause palpebral conjunctivitis; iron oxide fumes from weldh. can cause chronic bronchitis with continued exposure over 30 mg/m³; fresh iron oxide fumes can cause metal fume fever (195).

Synthesis:



Unique conditions, reaction products:

Incandescent reaction with ClF₃ (143).

Ignition temperature:

(99 through 270 mesh) 320°C (224).

Solubility:

i. hot and cold H₂O; s. acids, alkaline solvents, alcohol, ether (79)

Flammability:

Pyrophoric powder produced from Fe(OH)₃ if reduction temperature is lower than 550°C (80)

HAFNIUM

Mol. Wt.:

178.49

Formulas:

Hf

M.P.:

2330°C (79)

Characteristics:

Solid - hexagonal (79)

d./sp. gr.:

13.31 (79)

B.P.:

> 3200°C (79)

Synthesis

Thermal decomposition of its iodide, reduction of the tetrachloride or of the hydro-fluorohafnide with metallic sodium; reduction of the oxide with a mixture of calcium and sodium (132).

Ignition temperatures

Dust clouds: 20°C (68°F) (80)

Solubility

s. H₂; i. hot and cold H₂O (79)

Flammability

Spontaneously flammable (213)

POTASSIUM

Mol. Wt.:

39.102

Formulas

K

Synonyms:

Kallium

M.P.:

62.3°C (79)

Characteristics

Solid - silver cubic metal (79)

d./sp. gr.:

.86²⁰ (79)

B.P.:

760°C (79)

V.P.:

1³⁴¹ (195)

Toxicity:

High as irritant, on ingestion and on inhalation (195).

Synthesis

$\text{KN}_3 \rightarrow \text{K} + 3/2\text{N}_2$ (80)

Unique conditions, reaction products

Yields KOH + H₂ in reaction with H₂O; potassium melts and spatters and releases sufficient heat to ignite H₂ released, if confined may have explosion; potassium metal will form K₂O₂ and KO₂ or K₂O₄ at room temperature even if stored under mineral oil; may explode if handled or cut (195); ignites spontaneously in dry Cl, F and NO₂, is incandescent with CHO₃ and Na₂O₂ (142).

Solubility

d. to KOH in hot or cold H₂O; d. alcohol; s. acid, H₂, NH₃ (79).

Handling:

Store in inert atmosphere or under O₂ free liquid or in vacuum glass capsules, keep in detached fireproof buildings, do not heat in glass to melting point of potassium or a violent reaction with the glass takes place, dispose of by allowing small pieces to react with moisture in air and turn to potassium hydroxide (195).

Thermodynamic properties:

latent heat of vaporization: 496 cal/g (122)

heat of combustion: 43 kcal/mol (1,980 Btu/lb) (199)

Military and industrial uses

Used in synthesis of inorganic potassium compounds; in organic synthesis involving condensation, dehalogenation, reduction and polymerization reactions; used as heat transfer medium with sodium (132).

Flammability:

Can ignite spontaneously in moist air and burn, may explode (195).

LITHIUM

Mol. Wt.:
6.939

Formula:
Li

M.P.:
179°C (79)

Characteristics:
Solid - soft silver white (79)

d./sp. gr.:
.534²⁰ (79)

B.P.:
1317°C (79)

V.P.:
1723 (79)

Toxicity:

Slight, very caustic in H₂O (195).

Synthesis

- (1) LiBr electric arc, Li + 1/2 Br₂ (80)
- (2) Electrolysis of fused mixture of LiCl and KCl (108)
- (3) Reduce oxide with magnesium or aluminum (108)

Ignition temperature:

Autoignition temperature (in air): 180°C (143).

Solubility:

d. cold H₂O (79); dissolves (with evolution of H₂) in dilute HCl or H₂SO₄ (132); s. liquid NH₃ (132).

Handling:

Protect from physical damage; avoid H₂O, high temperatures and halogenated hydrocarbons (142); immerse in inert O₂ free solvent (108).

Thermodynamic properties

heat of fusion: 1,100 cal/mol
heat of vaporization: 32,300 cal/g mol } (108)
heat capacity (at 25°C): .814 cal/g°C
electrical resistivity: 45.25 μ ohms (at 230°C) (121)

Military and industrial uses

Possible use as propellant (108).

Flammability:

Spontaneously flammable in air (142).

MAGNESIUM

Mol. Wt.:
24.312

Formula:
Mg

M.P.:
651°C (79)

Characteristics
Solid - silver white hexagonal
metal (79)

d.sp. gr.:
1.745 (79)

B.P.:
1170°C (79)

V.P.:
1621 (195)

Toxicity:

Injurious if embedded in skin; irritant to respiratory tract (132).

Unique conditions, reaction products:

Spontaneously flammable with moist Fe and Cl; powdered Mg is incandescent with boron phosphide and explodes with chloroform or methyl chloride(143).

Ignition temperatures:

(86% passes through 270 mesh) 570°C (224).

Solubility:

1. cold H₂O, CrO₂, alkaline solvents; d. to Mg(OH)₂ in hot H₂O; s. mineral acids, concentrated HF, ammonium salts (79).

Handling:

Store away from oxidizing agents, protect from static electricity, keep containers grounded, and handle carefully (229).

Thermodynamic properties:

heat of formation (vaps) 35.907 cal/mol (at 298.1°C) (180)

heat of formation (sol): 0 (180)

dipole moment: 0 debye (180)

heat of fusion: 2.160 cal/mol (180)

heat of vaporization: 32,517 kcal/g atom (at 1107°C and 760 mm) (180)

heat of combustion: -146,100 cal/mol (181)

critical temperature: 2100°C (181)

electrical conductivity: 38.6 (132)

specific heat: 249 cal/g (132)

Military and industrial uses:

Used in light alloys, in the manufacture of precise instruments, in pyrotechnics, flash bulbs, and flares (132).

Flammability:

Fine powder dispersed in air presents dangerous fire and explosion hazard (229).

MANGANESE

Mol. Wt.:
54.93

Formula:
Mn

M.P.:
1212°C (79)

Characteristics:
Solid - grayish pink cubic or tetragonal metal (79)

d./sp. gr.:
7.44 (79)

B.P.:
2152°C (79)

V.P.:
11282 (79)

Toxicity:

Maximum allowable concentration is 5 mg/m³, high chronic systemic on inhalation; moderate acute systemic on inhalation (195).

Synthesis:

Electrolyze MnSO₄·4H₂O + (NH₄)₂SO₄ distill manganese prepared in this fashion, place in Al₂O₃ boat, establish a vacuum of at least .005 mmHg, heat to 1250-1350°C, distill metal deposits as small needles on a tubular nickel sleeve cooled by H₂O (cold) (80).

Unique conditions, reaction products:

Powdered manganese ignites and burns brilliantly in Cl, incandesces with F, incandesces and feebly explodes with HNO₃, ignites in NO₂ (143).

Ignition temperatures:

(63% can pass through 270 mesh): 450°C (40)

Solubility:

d. cold and hot H₂O; s. dilute acids (79)

Thermodynamic properties:

specific heat: 115 cal/g (132)

latent heat of fusion: 63.7 cal/g (132)

Flammability:

Product of synthesis extremely reactive and ignites upon exposure to air (80).

MOLYBDENUM

Mol. Wt.:
95.94

Formula:
Mo

M.P.:
2620 ± 10°C (79)

Characteristics:
Solid - silvery white metal to grayish black cubic powder (79)

d./sp. gr.:
10.2 (79)

B.P.:
4057/60 (79)

V.P.:
13102 (195)

Synthesis

- (1) $\text{MoO}_3 + 3\text{H}_2 \rightarrow \text{Mo} + 3\text{H}_2\text{O}$ (80)
(2) $3\text{MoO}_2 + 4\text{Al} \rightarrow 3\text{Mo} + 2\text{Al}_2\text{O}_3$ (80)

Unique conditions, reaction products

Incandescent reaction with ClF_3 , F. and PbO_2 (143).

Solubility

l. hot and cold H_2O ; s. hot concentrated HNO_3 , hot concentrated H_2SO_4 , aqua regia, HF and NH_3 ;
sl. s. HCl (79)

Flammability

Spontaneously flammable (240).

SODIUM

Mol. Wt.:

22.9898

Formulas

Na

Synonyms:

Natrium

M.P.:

97.5°C (79)

Characteristics

Solid - silvery cubic
metal (79)

d./sp. gr.:

.9720 (79)

B.P.:

883°C (79)

V.P.:

1.2400 (195)

$\frac{n_D}{t}$:

4.22 (79)

Toxicity

Acute local, (metallic sodium): slight irritant, high on ingestion and inhalation; (sodium smoke) moderate as irritant, high on ingestion, reacts exothermally with moisture of body or tissue surface causing thermal and chemical burns (195).

Synthesis

- (1) $2\text{Na}_2\text{MoO}_4 + \text{Zr} \rightarrow 4\text{Na} + \text{Zr}(\text{MoO}_4)_2$ (80)
(2) $2\text{Na}_2\text{WO}_4 + \text{Zr} \rightarrow 4\text{Na} + \text{Zr}(\text{WO}_4)_2$ (80)
(3) $\text{NaN}_3 \rightarrow \text{Na} + 3/2\text{N}_2$ (80)
(4) electrolytic production from fused NaCl (190)

Ignition temperatures

Autoignition temperatures above 115°C in dry air (195).

Solubility

d. cold H_2O to yield $\text{NaOH} + \text{H}_2$; d. alcohol; l. ether, C_6H_6 (79)

Handling:

Keep from moisture, O_2 or halides, use sufficient heat to prevent condensation (195).

Thermodynamic properties

dipole moment μ : 0 debye

heat of formation (at 298.1°C) (mol) .0

heat of formation (at 298.1°C) (vap) -25.949 cal/mol (182)

heat of fusion: 635 cal/g atom

heat of combustion: 50 kcal/mol (3,920 Btu/lb) (190)

Military and industrial uses

Used in the manufacture of sodium compounds, lead tetraethyl, used in organic synthesis, photoelectric cells and in sodium lamps (132)

Flammability

Violent reaction with H_2O liberating and igniting hydrogen (180).

Heated sodium spontaneously flammable in air (182).

NICKEL

Mol. Wt.:

58.71

Formula:

Ni

M.P.:

1455°C (79)

Characteristics

Solid - silver metal,
cubic (79)

d./sp. gr.:

8.90 (79)

B.P.:

2730°C (79)
2900°C (195)
3177°C (80)

V.P.:

11310 (195)

Toxicity

Large quantities cause nausea, vomiting, diarrhea, central nervous system depression and myocardial damage on ingestion (132).

Synthesis

(1) $NiO + H_2 \rightarrow Ni + H_2O$ (80)

(2) decompose nickel oxalate in vacuo at 350°-450°C (good yield)

(3) decompose nickel citrate in vacuo at 350°-450°C (poor yield) (71)

(4) decompose nickel formate in vacuo at 350°-450°C (poor yield)

Solubility

l. hot and cold H_2O , NH_3 ; sl. dilute HNO_3 ; sl. s. HCl , H_2SO_4 (79)

Military and industrial uses

Used in alloys, catalyst for hydrogenation of saponifiable oils (132).

Thermodynamic properties

specific heat (at 100°C): .1123

latent heat of fusion: 73 cal/g (132)

Mohs' hardness: 38

Flammability

Spontaneously flammable (80).

PHOSPHORUS
(White or Yellow)

Mol. Wt.:
123.8952

Formula:
 P_4

M.P.:
44.1°C (79)

Characteristics
Solid - yellow to white cubic
or wax like (79)

n_D^{20}
2.144 (79)

d./sp. gr.:
1.82²⁰ (79)

B.P.:
280°C (79)

V.P.:
176.6 (79)

Toxicity:

Fumes are an irritant but only slightly toxic; keep away from skin (causes severe, difficult to handle burns) (195).

Synthesis

Distill commercial phosphorus in CO_2 atmosphere to remove arsenic or melt white phosphorus (commercial) under dilute chromosulfuric acid, stir vigorously with glass rod and after solidification wash with distilled water (80).

Unique conditions, reaction products

Gives off dense white smoke of phosphorous pentoxide and phosphoric acid, smoke has great obscuring power (132).

Solubility

.000315 H_2O ; al. s. hot H_2O ; s. alcohol; 88010 CS_2 ; s. C_6H_6 , NH_3 , alkaline alcohol, ether, chlorine, $C_6H_5CH_3$ (79).

Handling

Handle with forceps, keep under water (132).

Military and industrial uses

Powerful incendiary, burning pieces adhere to skin and clothes, used by allies in World War II for screening smoke in hand grenades and mortars. Now used extensively for incendiary purposes in shells and bombs, used in matches (18); used as rat poisons, gas analysts, and with metals to form phosphides (132).

Flammability

Spontaneously flammable in air at 34°C (79).

PHOSPHOROUS
(red)

Mol. Wt.:
123.8952

Formula:
 P_4

M.P.:
590.43 (77)

Characteristics
Solid - reddish brown cubic
or amorphous powder (79)

d./sp. gr. at 25°C
2.34 (79)

B.P.:
Ignites 200°C (79)

V.D.:
4.77 g/cm³ (195)

Toxicity:

Slight as irritant, moderate on ingestion (195).

Synthesis:

Formed from white phosphorus at 240°C in absence of O₂ (216).

Unique conditions, reaction products:

Explosive when mixed with oxidizing materials (193).

Ignition temperatures:

Autoignition temperature 500°F (195).

Solubility:

v. sl. s. cold H₂O; i. hot H₂O, CS₂, alcohol, NH₃; s. absolute alcohol (79)

Handling:

Ship in cans or drums, protect from physical damage, store in cool place with adequate ventilation, separate from other materials (190).

Military and industrial uses:

Used in matches (214).

Flammability:

Commercial red phosphorus subject to spontaneous combustion in thick layers, critical thickness of layer defined by $Y = 2X = [K(T_0 - T_a)/Q]^{1/2}$ where Y = critical thickness of layer in centimeters, above which spontaneous combustion occurs, X = distance in cm from plane of wax, K = heat transfer coefficient. T₀ = autogenous temperature, T_a = ambient temperature, Q = heat of reaction in cal/cc/sec. The thickness of layer above which spontaneous combustion occurs is inversely proportional to the temperature of the rate of glisteration of heat which is directly proportional to the oxidation rate of red phosphorus (212).

LEAD

Mol. Wt.:
207.19

Formula:
Pb

M.P.:
327.43°C (79)

Characteristics
Solid - silvery bluish white
soft cubic metal (79)

d./sp. gr. at 20°C
11.288²⁰ (79)

B.P.:
1515°C (79)

V.P.:
1973 (195)

Synthesis

Decompose tartrate by heating over aluminum burner. dried crystal tartrate heated until gas generation ceases, heat beyond 500°-600°C lost pyrophoricity (76)

Solubility

1. hot and cold H_2O ; 1. HNO_3 , hot concentrated H_2SO_4 (79)

Thermodynamic properties

latent heat of fusion: 5.89 cal/g
latent heat of vaporization: 204.6 cal/g
electrical resistivity: 34.6 μ ohms (at 327°C) (121)
surface tension: 442 dynes/cm (at 350°C)

Flammability

Spontaneously flammable (115)

PLUTONIUM

Mol. Wt.:

242.00

Formulas:

Pu

M.P.:

639.5 \pm 2°C (79)

B.P.:

3235 \pm 19°C (79)

Toxicity:

Highly toxic. (195).

Synthesis

Obtained by neutron bombardment of U^{238} (57)

Military and industrial uses

Nuclear-reactor fuel and product (57).

Flammability:

Chips, turnings and fine particles spontaneously ignite (56).

RUBIDIUM

Mol. Wt.:

85.47

Formulas:

Rb

M.P.:

38.5°C (79)

Characteristics

Solid - silver white soft metal (79)

d./sp. gr.:

1.532 (sol) (79)

B.P.:

700°C (79)

V.P.:

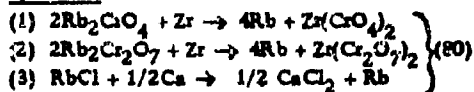
1297 (195)

1.47538.5 (liq) (79)

Toxicity:

Moderate (acute systemic) on injection; slight (chronic local, systemic) on ingestion (195).

Synthesis



Unique conditions, reaction products

Explosive reaction with acids and oxidizers (195)

Solubility

d. hot and cold H_2O , alcohol; s. acids (79)

Handling

Keep immersed in dry saturated hydrocarbon liquid or inert gas atmosphere (216).

Thermodynamic properties

resistivity: 8.81 $\mu\text{ohm/in.}$
ionization potentials: 4.126 volts
thermal conductivity (liq): 11.65 Btu/hr ft²F
thermal conductivity (vap): .00462 Btu/hr ft²F (216)
specific heat (liq): .0877 Btu/lb^oF
specific heat (vap): .0578 Btu/lb^oF
latent heat of fusion: 11.79 Btu/lb
latent heat of vaporization: 347.8 Btu/lb

Military and industrial uses

Used in rubidium salts, reagent in zeolite catalysts, and in photoelectric cells (132).

Flammability

Explosive reaction with H_2O (195); ignites spontaneously in dry air (216); heat of reaction with H_2O ignites hydrogen liberated (143).

SULFUR

Mol. Wt.:

256.512

Formula:

S₈

Synonyms:

Sulfur flour
Flowers of sulfur
Brimstone

M.P.:

α 95.5-112.8°C (79)
 β 118.75°C (79)
 γ about 120°C (79)

Characteristics

α Solid - yellow rhombic (79)
 β Solid - pale yellow
monoclinic (79)
 γ Solid - pale yellow
amorphous

d./sp/ gr.:

α 2.07²⁰ (79)
 β 1.96 (79)
 γ 1.92 (79)

B.P.:

α }
 β } 444.6°C (79)
 γ }

V.P.:

183.8 (195)

ⁿ_D

α 1.957 (79)

Toxicity:

Very low (195).

Synthesis:

Purify commercial sulfur by repeated recrystallization from CS_2 , or boil liquid sulfur with MgO and allow to stand at $125^\circ C$ overnight, filter settled black sludge through glass wool (MgO and sludge separate rapidly) treat clear filter four times in same manner (boil 25-30 hrs) cool very slowly get very pure sulfur (80).

Ignition temperatures:

Flash points: $405^\circ F$. (195)

Autoignition temperature: $450^\circ F$ (195)

Solubility:

1. hot and cold H_2O

α $23^\circ CS_2$; sl. s. $C_6H_5CH_3$, alcohol, C_6H_6 , ether, liquid NH_3 ; s. CCl_4 } (79)

β $70^\circ CS_2$; s. alcohol, C_6H_6

γ 1. CS_2

Military and industrial uses:

In H_2SO_4 , vulcanizing agent in rubber, ingredient in gunpowder, corrosion resistant cements, paper manufacture, plastics, and medicines (214).

Flammability:

Spontaneously flammable (211)

SILICON

Mol. Wt.:

28.086

Formula:

Si

M.P.:

$1410^\circ C$ (79)

Characteristics:

Solid - steel gray, large to micro cubic crystal (79)

d./sp. gr.:

2.32 - 2.34 (79)

B.P.:

$2355^\circ C$ (70)

V.P.:

11724 (79)

Unique conditions, reaction products:

Spontaneous burning in gaseous chlorine, reacts violently with AsF_3 (143).

Ignition temperatures:

(86% pass through 270 mesh) $775^\circ C$ (240).

Solubility:

1. hot and cold H_2O , HF ; s. HF and HNO_3 (79)

Flammability:

Spontaneously flammable dust (240).

TIN

Mol. Wt.:
118.69

Formula:
Sn

M.P.:
231.9°C (195)

Characteristics
Solid - gray cubic crystals (195)

d./sp. gr.:
5.75 (195)

B.P.:
2260°C (79)

V.P.:
1492 (195)

n_D^{20}
(liq) 2.1 (79)

Synthesis

Decompose tin oxalate or tin tartrate in vacuo at 350°-450°C (77).

Unique conditions, reaction products

Tin reacts with heated chlorine to yield light and more heat; Na_2O_2 oxidizes tin to incandescence (143).

Solubility:

sl. hot and cold H_2O ; s. HCl , H_2SO_4 , aqua regia, alkaline solvents; sl. s. HNO_3 (79)

Flammability:

Spontaneously flammable when finely divided (115).

STRONTIUM

Mol. Wt.:
87.62

Formula:
Sr

M.P.:
752°C (195)
774°C (79)

Characteristics
Solid - silver white to pale yellow metal (79)

d./sp. gr.:
2.620 (79)

B.P.:
1366°C (79)

V.P.:
10892 (79)

Synthesis

$\text{Sr}(\text{N}_3)_2 \rightarrow \text{Sr} + 3\text{N}_2$ (80)

Solubility:

s. liquid NH_3 , HNO_3 , HCl , dilute H_2SO_4 (132)

Military and industrial uses

Fireworks, red signal flares, tracer bullets (132).

Flammability:

If finely divided ignites on exposure to air (132).

TRITIUM

Mol. Wt.:
3.017 (27)

Formula:
 T_2

Characteristics:
Gas (27)

Military and industrial uses:
Radioactive tracer (132)

Flammability:
Spontaneously flammable (27)

THORIUM

Mol. Wt.:
232.038

Formula:
Th

M.P.:
1845°C (79)

Characteristics:
Solid - gray, cubic, radioactive (79)

d./sp. gr.:
11.7 (79)

B.P.:
4230°C (79)

Toxicity:
Cause dermatitis and certain radioactive hazards (195); possible safe concentration in air .1 mg/m³ (11).

Synthesis:

(1) $ThCl_4 + 4Na \rightarrow Th + 4NaCl$ (tetrachloride reduction with sodium)	} (80)
(2) $ThO_2 + 2Ca \rightarrow 2CaO + Th$ (oxide reduction)	
(3) $Th(NO_3)_4 \cdot 4H_2O \rightarrow KThF_6 \rightarrow Th$ (electrolysis)	
(4) $ThI_4 \rightarrow Th + 2I_2$ (refining process)	

Unique conditions, reaction products:
Incandescent reaction with chlorine (143).

Ignition temperatures:
(100% through 270 mesh) 270°C (240).

Solubility:
l. hot and cold H_2O ; s. HCl , H_2SO_4 , aqua regia; sl. s. HNO_3 (79).

Flammability:
Spontaneously flammable (high as powder, moderate as chips) (11).

URANIUM

Mol. Wt.:
238.03

Formula:
U

M.P.:
1132±1°C (79)

Characteristics:
Solid - silvery, cubic radio-
active (79)

d./sp. gr.:
19.05 ± .02²⁵ (79)

B.P.:
3818°C (79)

Toxicity:

High, radioactive, toxic when inhaled or swallowed, (chemical poison affects kidneys)
maximum acceptable concentration (ACGIH) .05 mg/m³ air (soluble uranium compounds);
.25 mg/m³ air (insoluble uranium compounds) (195).

Synthesis:

- (1) $\text{UO}_2 + 2\text{Ca} \rightarrow \text{U} + 2\text{CaO}$ (metallic calcium reduces oxide) (80)
- (2) Reduce U_3O_8 by freshly distilled calcium in high vacuum (yields very pure uranium) (80)
[$\text{CaCl}_2 + \text{BaCl}_2$ (prefused) added to reactant mixture above improves procedure] (80)
- (3) $\text{UCl}_4 + 4\text{Na} \rightarrow \text{U} + 4\text{NaCl}$ (80)
- (4) $\text{UCl}_5 + 5\text{Na} \rightarrow \text{U} + 5\text{NaCl}$ (80)

Unique conditions, reaction products:

Explosive reaction with HNO_3 ; ignites in warm NO_2 ; incandescent reaction with hot
Ss or S (143).

Ignition temperatures:

(100% through 270 mesh) 20°C (240).

Solubility:

1. hot and cold H_2O , alkaline solvent, alcohols & acids (79)

Thermodynamic properties:

specific heat (at 25°) 6.65 (132)
heat of fusion: 4.7 kcal/mol (132)

Flammability:

Powder spontaneously flammable, spontaneous ignition may result in intense heat and fumes;
if dry ignites in air, if dispersed in air explodes (12).

TUNGSTEN

Mol. Wt.:
183.85

Formula:
W

Synonyms:
Wolfram

M.P.:
3410°C (79)

Characteristics:
Solid - gray black cubic (79)

d./sp. gr.: 1
19.3520 (79)
4

B.P.: 1
5900760 (79)

V.P.: 1
13690 (195)

Synthesis

- (1) β tungsten is prepared by electrolysis and thermal reduction of WO_3 (194)
- (2) fluoridize W in vertically rising hydrogen stream and follow by reduction of WO_3 or ammonium paratungstate to pure tungsten powder (grain growth is suppressed by yellow oxide present as suspension) (222)

Solubility

1. cold and hot H_2O , HF, and KOH; v. sl. s. HNO_3 , H_2SO_4 , aqua regia; s. $HNO_3 + HF$ (79)

Thermodynamic properties

specific heat (at 20°C) 0.032 cal/g/°C (132)

heat of fusion 44 cal/g (132)

heat of vaporization 1150 cal/g (132)

Military and industrial uses

Increase hardness, toughness, elasticity and tensile strength of steel, manufacture alloys, filaments for incandescent lights and electron tubes, also used for contact points for automotive, telegraph, radio and TV apparatus (132).

Flammability

β -tungsten spontaneously flammable (194)

ZINC

Mol. Wt.: 1
65.37

Formula: 1
Zn

M.P.: 1
419.47°C (79)

Characterization: 1
Solid - bluish white hexagonal metal (79)

d./sp. gr.: 1
7.14 (79)

B.P.: 1
907760 (79)

V.P.: 1
1487 (195)

Toxicity

When heated it evolves fumes which cause "brass foundry's ague" (195); threshold limit of fumes 15 mg/m³ (143).

Synthesis

Decompose tartrate by heating over aluminum burner, heat dried crystal tartrates until gas generation ceases, if heat to 500°-600°C loses pyrophoricity (76).

Unique conditions, reaction products

Evolved H_2 with alkali hydroxides (132); incandescent reaction with CS_2 , burns in moist chlorine, explodes with heat with Manganese chloride or Potassium nitrate; incandescent reaction with selenium or tellurium or Na_2O_2 (143).

Ignition temperatures:

(100% through 370 mesh): 500°C (242)

Solubility:

1. hot and cold H₂O; s. acids, alkaline solvent, acetic acid (79)

Handling:

Protect from physical damage, store in cool, dry, well ventilated place, separate from acids, halogenated hydrocarbons and strong alkali hydroxides, protect from moisture (142).

Thermodynamic properties:

Mohs' hardness: 2.5 (195)

electrochemical equivalent: 1.220 g/amp hr (195)

Military and industrial uses:

Used in alloys, galvanizing iron and other metals, electroplating, fuses (electrical), and anodes (190).

Flammability:

Bulk dust in damp state may heat spontaneously and ignite on exposure to air (142).

ZIRCONIUM

Mol. Wt.:

91.22

Formulas:

Zr

M.P.:

1857°C (79)

Characteristics:

Solid - silver gray metal (79)

d./sp. gr.:

6.49 (79)

B.P.:

>2900°C (79)

Toxicity:

Threshold value 5 mg/m³ air; low for acute and chronic exposures (195).

Synthesis:

- (1) $ZrI_4 \rightarrow Zr + 2I_2$
- (2) $ZrO_2 + 2Ca \rightarrow Zr + 2CaO$
- (3) $K_2ZrF_6 + 4Na \rightarrow Zr + 2KF + 4NaF$ (80)
- (4) $ZrCl_4 + 4Na \rightarrow Zr + 4NaCl$
- (5) $ZrCl_4 + 2Mg \rightarrow Zr + 2MgCl_2$

Unique conditions, reaction products:

With borax explodes when heated, explodes violently with cupric oxide, slight explosion with potassium chlorate and heat or potassium nitrate and heat (143).

Ignition temperatures:

304°F (27)

Autoignition temperature: 500°F (195)

Solubility:

i. hot and cold H_2O ; s. HF, aqua regia; al. s. CH_3COOH (79)

Handling:

Ship in glass or metal containers inside wooden boxes, metal barrels. Protect from physical damage, isolate from oxidizing materials (142).

Thermodynamic properties

Brinell hardness: 85 (132)

Military and industrial uses:

Structural material for atomic reactors (132)

Flammability:

Powder spontaneously flammable in air (27).

(b) ALLOYS

CERIUM AMALGAM

Mol. Wt.:

CeHg₄ 942.57

CeHg₄ 541.35

CeHg 280.26

Formulas:

CeHg₄
CeHg₂ } (84)
CeHg

Flammability:

Spontaneously flammable in air (233)

CERIUM-INDIUM ALLOYS

Mol. Wt.:

Ce₂In 395.06

CeIn 254.94

Ce₂In₃ 624.70

Formulas:

Ce₂In
CeIn } (235)
Ce₂In₃

Unique conditions, reaction products:

CeIn₃ not pyrophoric (235)

Military and industrial uses:

Spontaneously flammable alloys, 0%-30% Ce alloy has the greatest pyrophoricity (235).

CERIUM HYDRIDE AMALGAM

Formulas:

(CeH₂)_x(Hg)_y

Flammability:

Concentrated mixtures of CeH₂ and Hg on admission to air rapidly develop a luminous black precipitate and ignite spontaneously, black precipitate reasonably pure CeH₂; CeH₂ amalgam broken under water results in a vigorous reaction evolving H₂ and sparks (215).

COBALT AMALGAM

Formulas:

(Co)_x(Hg)_y

Characteristics:

Solid - gray to black
powder (169)

Synthesis

(1) Electrolytic reduction of cobalt by a mercury cathode forms a suspension of fine metal powder in mercury, separation of mercury by vacuum distillation yields cobalt amalgam (159); (2) react sodium amalgam and concentrated solution of cobalt chloride; (3) potassium amalgam in solution of cobaltous chloride sulphate or nitrate; react zinc amalgam in aqueous solution of cobaltous chloride saturated with ammonia (yields hydrogen) (131).

Solubility

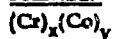
sl. d. H_2O ; l. Hg (131).

Flammability

Spontaneously flammable (169).

CHROMIUM-COBALT ALLOY

Formulas



Characteristics

Solid - tetragonal crystals (CoCr) (131)

Unique conditions, reaction products

Miscible in all proportions, minimum crystallization temperature is $1320^{\circ}C$ when fused mass has 47% chromium, structural change at $1226^{\circ}C$ with 30-100% chromium (131).

Flammability

When smaller than 1μ are spontaneously flammable alloys (240).

CESIUM ARSENIC ALLOY

Mol. Wt.:

473.65

Formula:



Flammability

Spontaneously flammable (240).

CESIUM BISMUTH ALLOY

Mol. Wt.:

682.64

Formula:



Flammability

Spontaneously flammable (240).

CESIUM-ANTIMONY ALLOY

Mol. Wt.:

(Cs₃Sb) 595.41
(Cs₅Sb₄) 487.04

Formulas:

Cs₃Sb
Cs₅Sb₄

Flammability:

Spontaneously flammable (240).

IRON AMALGAM

Formulas:

(Fe)_x(Hg)_y

Characteristics:

Solid - gray to black powder (169)

Synthesis:

Electrolytic reduction of iron by a mercury cathode forms a suspension of fine metal powder in mercury, separation of mercury by vacuum distillation yields iron amalgam (169).

Flammability:

Spontaneously flammable (169).

POTASSIUM ARSENIC ALLOY

Formulas:

(K)_x(As)_y

Flammability:

Spontaneously flammable (240).

POTASSIUM-PHOSPHORUS ALLOY

Mol. Wt.:

148.27

Formulas:

K₃P

Flammability:

Spontaneously flammable (240).

POTASSIUM-ANTIMONY ALLOY

Mol. Wt.:

(K₃Sb) 239.06
(K₅Sb₄) 682.54

Formulas:

K₃Sb
K₅Sb₄

Thermodynamic properties:

heat of formation (K₃Sb): -17850 ±2000 cal/g atom (at 298°K) (87).

Flammability:

Spontaneously flammable (240).

LANTHUM-ANTIMONY ALLOY

Mol. Wt.:

(La₂Sb) 369.60

(LaSb) 259.68

(LaSb₂) 382.44

Formulas

La₂Sb

LaSb

LaSb₂

(235)

Flammability:

Spontaneously flammable (235).

LITHIUM PHOSPHORUS ALLOY

Mol. Wt.:

37.91

Formulas

LiP

Flammability:

Spontaneously flammable (240).

MANGANESE-BISMUTH ALLOY

Mol. Wt.:

263.93

Formulas

MnBi

Synthesis

Alloy prepared through melting a stoichiometric mixture of manganese and bismuth becomes pyrophoric after mechanical comminution (240).

Flammability:

Spontaneously flammable (240).

SODIUM AMALGAM

Mol. Wt.:

(Hg₃Na) 624.82

(Hg₈Na₇) 1765.81

(Hg₂Na₅) 518.17

(Hg₄Na) 825.43

(Hg₂Na) 424.21

(HgNa) 223.60

(Hg₂Na₃) 470.19

Formulas

Hg₃Na, Hg₈Na₇, Hg₂Na₅, Hg₂Na₃,
Hg₄Na, Hg₂Na, HgNa, Hg₂Na₅ (85)

Characteristics

Hg₂Na Solid-hexagonal c-32 ordered structure

HgNa Solid-orthogonal crystal

Hg₂Na₃ Solid tetragonal crystal

Hg₂Na₅ Solid rhombic crystal

Hg₄Na Solid-hexagonal

(85)

Synthesis

(1) Clean sodium metal is cubed (5 mm), spear with pointed glass rod and rapidly introduce below

surface of warm (30°-40°C) pure mercury (80); (2) protect sodium by layer of toluene and kerosene, then add mercury in drops (80).

Unique conditions, reaction products

Moisture hazardous solid, decomposes water to yield hydrogen (27).

Flammability

Liable to produce fire upon becoming moist or in contact with water (27).

SODIUM-POTASSIUM ALLOY

Formula

$(\text{Na})_x(\text{K})_y$ (40-90%K)

Characteristics

Liquid - silvery white to yellow
orange (in air) (142)

Toxicity

Liquid causes severe skin and eye burns (142).

Unique conditions, reaction products

Reacts with water, generates sufficient heat to ignite the hydrogen produced in the presence of air (198); reacts violently with CCl_4 and CO_2 (142).

Handling

Protect from physical damage and keep away from water, avoid high temperature (142).

Thermodynamic properties

ΔH_f Gibbs free energy	
40% 245 cal/g atom	} (36)
60% 245 cal/g atom	
80% 190 cal/g atom	
90% 135 cal/g atom	

Military and industrial uses

Used as efficient heat transfer medium in some nuclear power developments, certain engines and unipolar generators, in unipolar machines serves as current collector for high rotor currents (198).

Flammability

Spontaneously flammable in air above 115°C (139).

SODIUM LEAD ALLOY

Mol. Wt.:

$(\text{Na}_{15}\text{Pb}_4)$ 1173.69	} (88)
(Na_5Pb_2) 529.37	
(Na_3Pb) 1635.75	
(NaPb) 230.20	

Formula

$(\text{Na})_x(\text{Pb})_y$

Thermodynamic properties

<u>xPb</u>	<u>Gibbs free energy</u>	<u>Enthalpy</u>	<u>Entropy</u>	
.2 ($\text{Na}_{15}\text{Pb}_4$)	-3800 cal/g atom	-400 cal/g atom	-.7 cal/'Kg atom	} (88)
.286 (Na_5Pb_2)	-4900 cal/g atom	-5000 cal/g atom	-.4 cal/'Kg atom	
.306 (Na_9Pb_4)	-5000 cal/g atom	-5200 cal/g atom	-.7 cal/'Kg atom	
.50 (NaPb)	-5350 cal/g atom	-5800 cal/g atom	-1.5 cal/'Kg atom	
.70 (B)	-3450 cal/g atom (± 400)	-3300 cal/g atom (± 500)	-.6 cal/'Kg atom (± 1.0)	

Flammability:

When wet yields H_2 which may ignite spontaneously (27).

NICKEL-IRON ALLOY

Formula:

$(\text{Ni})_x(\text{Fe})_y$

Unites in all proportions (131)

Synthesis

Combine iron and nickel oxalate in nitrogen, reduce with hydrogen at 150°C to yield iron-nickel alloy (240).

Flammability:

Spontaneously flammable alloy (240).

NICKEL LANTHANUM

Mol. Wt.:

256.34

Formula:

Ni_2La (239)

Flammability:

Spontaneously flammable (238)

RUBIDIUM-ARSENIC ALLOY

Mol. Wt.:

331.36

Formula:

Rb_3As (240)

Flammability:

Spontaneously flammable (240)

RUBIDIUM-BISMUTH ALLOY

Formula:

Rb_3Bi (240)

Flammability:

Spontaneously flammable (240).

RUBIDIUM-ANTIMONY ALLOY

<u>Mol. Wt.:</u>	<u>Formula:</u>
(Rb ₃ Sb) 378.20	Rb ₃ Sb (240)
(Rb ₅ Sb ₄) 487.04	Rb ₅ Sb ₄

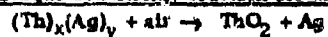
Flammability:

Spontaneously flammable (240).

THORIUM SILVER ALLOY

<u>Formula:</u>
(Th) _x (Ag) _y

Unique conditions, reaction products



Flammability:

The self-ignition of silver-thorium alloys is based on the spontaneous oxidation of thorium following the decomposition of H₂O. The hydrogen evolved by the decomposition of H₂O burns catalytically under the influence of silver, the energy thereby governing the spontaneous oxidation of thorium (183).

URANIUM-BISMUTH ALLOY

<u>Mol. Wt.:</u>	<u>Formula:</u>
(UBi) 447.06	UBi
(U ₃ Bi ₄) 1342.17	U ₃ Bi ₄ } (240)
(UBi ₂) 656.05	UBi ₂ }

Flammability:

Spontaneously flammable (over 30% U very pyrophoric) (240).

(c) AMIDES, IMIDES

CADMIUM AMIDE

Mol. Wt.:
144.45

Formula:
 $\text{Cd}(\text{NH}_2)_2$

M.P.:
d. 120°C (79)

d./sp. gr.:
3.05²⁵ (79)

Synthesis
 $\text{Cd}(\text{SCN})_2 + 2\text{KNH}_2 \rightarrow \text{Cd}(\text{NH}_2)_2 + 2\text{KSCN}$ (80)

Flammability:
Spontaneous heating and possible explosion with H_2O (143).

CESIUM AMIDE

Mol. Wt.:
148.93

Formula:
 CsNH_2

M.P.:
 $262 \pm 1^\circ\text{C}$ (79)

Characteristics
Solid - white needles (79)

d./sp. gr.:
3.44²⁵ (79)

Synthesis
By action of ammonia on cesium hydride, allow cesium ammonium to stand for some time (131).

Solubility:
d. cold H_2O ; s. liquid NH_3 (75)

Thermodynamic properties
standard heat of formation -25.4 kcal/mol (79)

Flammability:
Incandescent in air (143).

LITHIUM AMIDE

Mol. Wt.:
22.96

Formula:
 LiNH_2

M.P.:
300°-400°C (132)

Characteristics:
Solid - colorless cubic
needles (79)

d./sp. gr.:
1.178/17.5 (132)

Synthesis:
 $\text{Li} + \text{NH}_3 \rightarrow \text{LiNH}_2 + 1/2\text{H}_2$ (132)

Unique conditions, reaction products:
Sublimes in NH_3 current (132); $\text{LiNH}_2 + \text{H}_2\text{O} \rightarrow \text{LiOH} + \text{NH}_3$ (132).

Solubility:
s. cold H_2O ; d. hot H_2O ; sl. s. liquid NH_3 , alcohol; i. ether, C_6H_6 (79)

Thermodynamic properties:
heat of formation: 42 kcal/g mol (at 18°C and 760 mm) (132)

Flammability:
Reacts with moisture yielding a dangerous amount of heat (27)

LITHIUM DIMETHYLAMIDE

Mol. Wt.:
50.96

Formula:
 $\text{LiN}(\text{CH}_3)_2$

Characteristics:
Solid - white (53)

Flammability:
Spontaneously flammable (53)

MAGNESIUM DIAMIDE

Mol. Wt.:
56.36

Formula:
 $\text{Mg}(\text{NH}_2)_2$

M.P.:
d. 350°-400°C (79)

B.P.:
decomposes (79)

Characteristics:
Solid - gray powder (79)

Synthesis:
(1) from action of ammonia on ether solution of $\text{Mg}(\text{C}_2\text{H}_5)_2$ or (2) on Mg activated with I_2 at 400°C (132).

Unique conditions, reaction products:
Violent reaction with water to yield ammonia gas (195).

Solubility:
d. cold H_2O alcohol; v. sl. s. liquid NH_3 (79).

Flammability:

Spontaneously flammable in air (195).

SODIUM AMIDE

Mol. Wt.:

39.01

Formula:

$\text{Na}(\text{NH}_2)$

Synonyms:

Sodamide

M.P.:

$\geq 10^\circ\text{C}$ (79)

Characteristics:

Solid - white (79)

B.P.:

400°C (79)

Synthesis:

$\text{Na} + \text{NH}_3 \xrightarrow{300^\circ\text{C}} \text{NaNH}_2 + 1/2\text{H}_2$ (80)

Unique conditions, reaction products:

If heated to decomposition it yields highly toxic fumes of ammonia and sodium oxide, reacts with water or steam to yield heat and toxic corrosive fumes (195).

Solubility:

d. hot and cold H_2O , hot alcohol; .1 liquid NH_3 (79).

Handling:

Store in sealed containers which prevent contact with air because sodium amide is hydrolyzed by atmospheric moisture; gradual oxidation produces mixtures that detonate on heating (132).

Thermodynamic properties:

heat of solution -31.06 (at 21°C) (132)

standard heat of formation -28.4 kcal/mol (79)

Military and industrial uses:

As a dehydrating agent, in the production of indigo and hydrazine, and as an intermediate in the preparation of sodium cyanide (132).

Flammability:

Flames with small amount of water (50).

LEAD AMIDE

Mol. Wt.:

322.21

Formula:

PbNH

Characteristics:

Solid - orange red (131)

Synthesis:

Treat liquid ammonia solution of potassium amide with a solution of lead iodide, and an orange red precipitate of PbNH is slowly formed (131).

Unique conditions, reaction products

Explodes with heat or dilute acid (131).

Solubility

d. dilute CH_3COOH , dilute potash lye; slow d. steam (131).

Flammability

Explodes with H_2O (143).

(d) CARBIDES

BARIUM CARBIDE

Mol. Wt.:
161.36

Formula:
 BaC_2

d./sp. gr.:
3.75 (79)

Characteristics:
Solid - gray crystal (79)

Synthesis:

Fusion of barium carbonate, powdered magnesium and retort carbon results in an intense reaction yielding barium carbide. $[\text{BaCO}_3 + 3\text{Mg} + \text{C} \rightarrow 3\text{MgO} + \text{BaC}_2]$ (131).

Unique conditions, reaction products:

Evolves acetylene vapor in contact with moisture (195).

Solubility:

d. cold H_2O to yield C_2H_2 ; d. acid (195).

Flammability:

Burns into flames on contact with small amounts of H_2O (50).

CALCIUM CARBIDE

Mol. Wt.:
64.10

Formula:
 CaC_2

d./sp. gr.:
2.22 (103)

Characteristics:
Solid - white tetragonal (103)

B.P.:
 2300°C (195)

$\frac{n_D}{t}$
 > 1.175 (79)

Toxicity:

Dust is an eye and respiratory irritant, can cause skin burns (142).

Synthesis:

- (1) Heat lime and carbon in an electric furnace (132)
(2) $\text{CaO} + 3\text{C} \rightarrow \text{CaC}_2 + \text{CO}$
(3) $\text{CaCN}_2 \rightarrow \text{CaC}_2 + 2\text{N}_2 + \text{Ca}$
(4) $\text{CaCN}_2 + \text{C} \rightarrow \text{CaC}_2 + \text{N}_2$ } (80)

Unique conditions, reaction products:

Yields acetylene and hydrated lime on contact with moisture (132).

Solubility:

d. hot and cold H_2O (103).

Handling:

Protect against physical damage, store in noncombustible, well ventilated area (without sprinkler protection) exclude other possible sources of ignition (142).

Military and industrial uses:

Used to produce acetylene for lighting purposes, as a reducing agent, in signal fires for marine service, and to weld and cut metals (132).

Flammability:

Produces sufficient heat to ignite acetylene formed on contact with water or moisture (142).

POTASSIUM GRAPHITE

Mol. Wt.:

KC₈ 135.1

KC₂₄ 327.1

Formulas:

KC₈

KC₂₄

Characteristics:

KC₈ Solid-dark copper red to bronze

KC₂₄ Solid-steel blue (79)

Unique conditions, reaction products:

Sensitive to air, moisture and alcohol (195).

Flammability:

Spontaneously flammable in air (80).

POTASSIUM CARBIDE

Mol. Wt.:

64.13

Formulas:

KHC₂

d./sp. gr.:

1.37 (79)

Characteristics:

Solid - colorless rhombic crystals (79)

Unique conditions, reaction products:

Explosive reaction with H₂O (143).

SODIUM CARBIDE

Mol. Wt.:

70.00

Formulas:

Na₂C₂

M.P.:

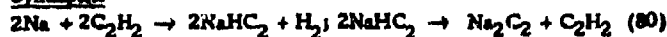
About 700°C (79)

Characteristics:

Solid - white powder (79)

d./sp. gr.:
1.57515 (79)

Synthesis



Unique conditions, reaction products

Reacts with H_2O producing H_2 so violently that an explosion can occur (232).

Solubility:

d. cold H_2O , hot H_2O , alcohol; s. acid (79)

TITANIUM CARBIDE

Mol. Wt.:
59.91

Formula:
 TiC

M.P.:
 $3140^\circ \pm 90^\circ\text{C}$ (79)

Characteristics
Solid - gray cubic metal (79)

d./sp. gr.:
4.93 (79)

B.P.:
 4820°C (79)

Synthesis

Heat titanic oxide (160 parts) and carbon (70 parts) in an electric arc furnace for 10 minutes [$\text{TiO}_2 + 2\text{C} \rightarrow \text{TiC} + \text{CO}_2$] (131).

Solubility:

i. cold and hot H_2O ; s. aqua regia, HNO_3 (79)

Military and industrial uses

Additive with tungsten carbide in making cutting tools and other tools (parts) subjected to thermal shock, arc-melting electrodes; cermets (190).

Flammability:

"As micron-sized titanium carbide was being removed from a ball mill, a cloud of the dust ignited." (143).

URANIUM MONOCARBIDE

Mol. Wt.:
250.07

Formula:
 UC

M.P.:
 $2.315 \pm 65^\circ\text{C}$ (193)

d./sp. gr.:
12.97 (193)

Synthesis



Unique conditions, reaction products

Reactive with water (193).

Thermodynamic properties

Thermal conductivity: .06 cal/sec/cm/°C (at 100° to 700°C and 5 weight % C) (193)

Military and industrial uses

Used as fissionable dust carried in a gas in an ADFR (Armour dust fissionable reactor), gas was helium, graphite was used as a moderator and the ducts and chambers were lined with silicon carbide (112).

Flammability:

Less than 40μ very pyrophoric (240).

URANIUM CARBIDE

Mol. Wt.:

262.05

Formula:

UC₂

M.P.:

2350°-2400°C (79)

Characteristics

Solid - metallic crystal (79)

d./sp. gr.:

11.2816 (79)

B.P.:

4370°/60 (79)

Solubility:

d. cold and hot H₂O, dilute inorganic acids; i. alcohol (79)

Flammability:

Spontaneously flammable if particle size less than 40μ (240).

ZIRCONIUM CARBIDE

Mol. Wt.:

103.23

Formula:

ZrC

M.P.:

3540°C (190)

Characteristics

Solid - gray cubic metal (79)

d./sp. gr.:

5.78 (190)

B.P.:

5100°C (190)

Hardness

.84 mohrs (190)

Synthesis

Heat zirconium oxide and coke in an electric furnace (190).

Solubility:

1. H_2O , HCl ; s. oxidizing acids (190).

Military and industrial uses

Incandescent filament, abrasive, high temperature electrical conductor (190).

Flammability:

Fine powder spontaneously flammable (190)

ZIRCON CARBIDE OR ZIRCON CARBONITRIDE

Synthesis

Heat Zircon mineral and carbon in an electric arc furnace to yield Zircon carbide or carbonitride (14).

Flammability:

"Air must be kept away from compound as it cools, or it may go up in a spontaneous display ... " (44).

(e) CARBONYLS

IRON PENTACARBONYL

Mol. Wt.:
195.90

Formulas
 $\text{Fe}(\text{CO})_5$

M.P.:
-21°C (79)

Characteristics
Liquid - viscous yellow (79)

d./sp.gr.:
1.45721 (79)

B.P.:
102.8749 (79)

Toxicity:

Causes dizziness, nausea, and vomiting on inhalation, followed by unconsciousness, can injure liver, kidneys and brain (195).

Synthesis:

$\text{Fe} + 5\text{CO} \xrightarrow[\Delta]{\text{pressure}} \text{Fe}(\text{CO})_5$ (80)

Ignition temperatures:

flash points 5°F (195)

Solubility:

l. cold H_2O ; s. alcohol, ether, C_6H_6 , alkaline solvents, concentrated H_2SO_4 (79)

Thermodynamic properties:

dipole moments .64-.81
heat of formation (at 18°C) -189.5 kcal/mol
heat of fusion 3.25 kcal/mol.
heat of vaporization 9.0 kcal/mol

} (132)

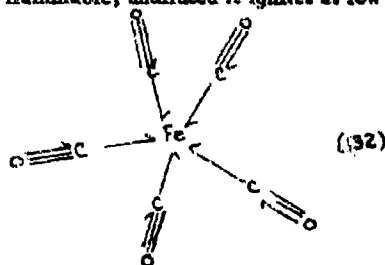
Military and industrial uses:

Used to make carbonyl iron, formerly as antiknock agent in motor fuels (132).

Flammability:

Spontaneously flammable; undiluted it ignites as low as 44°C (99)

Structure:



POTASSIUM CARBONYL

M. Wt.:
402.68

Formulas
 $(\text{KCO})_6$

M.P.:
Explodes (79)

Characteristics:
Gray-red (79)

B.P.:
d. 250°C (103)

Toxicity:
Highly toxic (195)

Solubility:
Explodes with cold H₂O; d. alcohol (79).

Synthesis:
Pass dry purified CO into a solution of potassiummanganium in liquified ammonia at -50°C, blue color gradually becomes weaker and changes to pink, allow ammonia to evaporate, yields K(CO)₆ (131).

Flammability:
Detonates with air, H₂O or heat (100°C) (131).

SODIUM CARBONYL

Mol. Wt.:
79

Formulas:
Na(CO)₂

Characteristics:
Solid - white powder,
black-tint (131)

Toxicity:
Highly toxic (295).

Unique conditions, reaction products:
Explodes with air or H₂O (143).

Synthesis:
Pass pure dry CO into solution of sodammonium in liquified ammonia at about -50°C, blue color becomes lilac tinted, evaporate ammonia, leaving Na(CO)₂ (131).

NICKEL CARBONYL

Mol. Wt.:
370.75

Formulas:
Ni(CO)₄

M.P.:
-25°C (79)

Characteristics:
Liquid - colorless volatile or
solid - needles (79)

d./sp. gr.:
1.3217 (79)

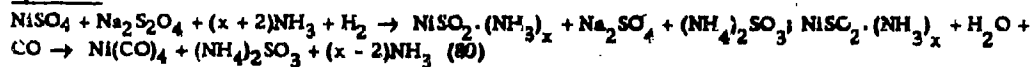
B.P.:
43°C (79)

V.P.:
400-25.8 (35)

Toxicity

High on inhalation (local and systemic); slight allergen; high on inhalation (chronic systemic); Tolerance level ACGIH .001 ppm (.007 mg/m³) (195).

Synthesis



Solubility

s. aqua regia, alcohol, ether, C₆H₆, HNO₃; i. dilute acid, dilute alkaline solvent (79).

Flammability

In the presence of air, Ni(CO)₄ forms a deposit which becomes peroxidized, this tends to decompose and ignite (143).

DIVANADIUM DODECACARBONYL

Mol. Wt.:
438.02

Formula:
V₂(CO)₁₂

Characteristics

Dark blue solution, gives yellow to orange solution in toluene (175)

Synthesis

Isolated from reaction of ditoluene vanadium and carbon monoxide (175).

Unique conditions, reaction products

Volatile, readily sublimes at room temperature and atmospheric pressure (175).

Solubility

s. ether, hydrocarbons; d. CS₂ (175).

Flammability

Spontaneously flammable (1/5).

(f) HALIDES

ARSENIC TRICHLORIDE

Mol. Wt.:
181.28

Formula:
AsCl3

M. P.:
-8.5°C (79)

Characteristics:
Liquid - oily (190)

d./sp. gr.:
2.163²⁰ (79)

B. P.:
63.752 (79)

n_D^{14°F}:
1.621 (79)

Synthesis

(1) from action of chlorine on arsenic; (2) distill arsenic trioxide with concentrated HCl (190).

Unique conditions, reaction products

Fumes in moist air (190).

Solubility:

s. HCl, HBr, PCl₃, alcohol, ether; d. hot and cold H₂O (79).

Thermodynamic properties

	<u>Gas</u>	<u>Liquid</u>	
standard heat of formation	-71.5 kcal/mol	-80.2 kcal/mol	} (79)
standard free energy of formation	-62.5 kcal/mol	-70.5 kcal/mol	
entropy (at 25°C)	78.2 e.u.	55.5 e.u.	

Military and industrial uses

Used in poison gas and ceramics (190).

BORON ARSENOTRIBROMIDE

Mol. Wt.:
328.47

Formula:
BBr3AsH3

Flammability:

With air or oxygen it is readily oxidized and in most cases ignites spontaneously (143).

BORON TRIBROMIDE

Mol. Wt.:
250.54

Formula:
B(Br)3

M. P.:
-46°C (79)

Characteristics:
Liquid - colorless fuming

d./sp. gr.:
2.6431^{18.4}₄ (79)

B.P.:
91.3 ± .25°C (79)

D₄:
16.3 (79)

Synthesis

- (1) $\text{AlBr}_3 + \text{BF}_3 \rightarrow \text{BBr}_3 + \text{AlF}_3$ (80)
(2) $\text{B} + 1/2\text{Br}_2 \rightarrow \text{BBr}_3$

Unique conditions, reaction products

Explodes with H_2O (143).

Solubility

d. cold H_2O ; s. alcohol, CCl_4 (79)

Thermodynamic properties

	<u>Solid</u>	<u>Liquid</u>	
standard heat of formation:	-44.6 kcal/mol	-52.8 kcal/mol	} (79)
standard free energy of formation:	-51.0 kcal/mol	-52.4 kcal/mol	
entropy (at 25°C):	77.49 e.u.	54.7 e.u.	

TETRACHLORODIBORANE

Mol. Wt.:
163.47

Formula:
 B_2Cl_4

M.P.:
-91°C (226)

Characteristics
Liquid colorless (226)

B.P.:
65.5°C (226)

Solubility

d. H_2O (226)

Synthesis

Made by passing BCl_3 through a discharge between mercury electrodes (230).

Thermodynamic properties

heat of fusion: 2579 ± 4 cal/mol
heat of vaporization (at 220°K): 8670 ± 70 cal/mol } (155)
entropy (at 1 atmosphere and 220°K): 80.27 e.u. }

Flammability

Spontaneously flammable (226); May be due to presence of BCl_3 , even though carefully purified (230).

MONOCHLORODIBORANE

Mol. Wt.:
62.14

Formula:
 $\text{B}_2\text{BH}_2\text{Cl}$

M.P.:
-112°C (226)

Characteristics
Gas - colorless (226)

B.P.:
0°C (226)

Solubility:

s. organic solvents; d. H_2O , air (226).

Flammability:

Spontaneously flammable (226).

BORON CHLORIDE TETRAMER

Mol. Wt.:

185.12

Formula:

$(BCl)_4$

M.P.:

d. $75^\circ C$ (226)

Characteristics:

Solid - yellow crystals (226)

V.P.:

231.5
6834 (226)

Flammability:

Spontaneously flammable (226).

BISMUTH PENTAFLUORIDE

Mol. Wt.:

304.00

Formula:

BiF_5

M.P.:

Sublimes at $550^\circ C$ (195)

Characteristics:

Solid - white crystal (195)

Toxicity:

Highly toxic and irritating to mucous membranes, skin, eyes, and respiratory tract (195).

Synthesis:

$BiF_3 + F_2 \rightarrow BiF_5$ (80)

Unique conditions, reaction products:

Reacts violently with water and petrolatum (195).

Flammability:

Reacts with H_2O sometimes with ignition (80).

BROMINE PENTAFLUORIDE

Mol. Wt.:

174.90

Formula:

BrF_5

M.P.:

$-61.3^\circ C$ (79)

Characteristics:

Liquid - colorless (79)

V.P.:

7 psia (at $70^\circ F$) (190)

d./sp. gr.:

2.570 (79)

B.P.:

$40.5^\circ C$ (79)

V.d.:

6.05 (195)

Toxicity:

High (acute, local) as irritant, on ingestion and on inhalation; high (chronic, local) as irritant, on ingestion and on inhalation (195).

Synthesis:

Nearly explosive reaction with H_2O ; fumes strongly in air (80).

Solubility:

d. hot and cold H_2O (79)

Military and industrial uses:

Oxidizer in liquid rocket propellants (190).

CALCIUM HYPOCHLORITE (With > 30% available chlorine)

Mol. Wt.:

91.53

Formula:

$CaOCl$

Unique conditions, reaction products:

Decomposes in H_2O ; with heat or sun may decompose, spontaneously rupturing container; vapors evolved may ignite spontaneously in air (54).

CHLORINE TRIFLUORIDE

Mol. Wt.:

92.45

Formula:

ClF_3

M.P.:

$-83^\circ C$ (79)

Characteristics:

Gas - colorless, sweet odor (79)

V.d.:

3.14 (79)

F.P. $-105^\circ C$ (150)

B.P.:

$11.3^\circ C$ (79)

Viscosity (liq): (1)

.438 cp (at $67^\circ F$)

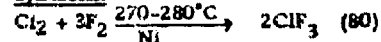
d./sp. gr.:

1.7713 (79)

Toxicity:

Emits highly toxic fumes with H_2O , $-COOH$, or acid fumes (195); strongly attacks bronchi (80); MAC (Maximum acceptable concentration) .1 ppm (1).

Synthesis:



Unique conditions, reaction products:

Ignites on contact with many organic compounds, reacts violently with oxidizable materials (195); reacts violently with H_2O (62).

Solubility:

d. cold and hot H_2O (79)

Handling:

Keep free from excessive heat and moisture in stainless steel tanks or calcium alloys, position tanks so that they cannot be easily tipped over or rolled (30).

Thermodynamic properties:

heat of fusion (at freezing point): 35.45 Btu/lb
heat of vaporization (at freezing point): 128.3 Btu/lb
heat capacity (at 68°F) (gas): .169 Btu/lb
heat capacity (liq): .304 Btu/lb
critical temperature: 345.2°F
critical pressure: 837.7 psia

Military and industrial uses:

Used as incendiary material by the military in World War II, used more recently as a fluorinating agent and as an oxidizer in rocket engines (62).

Flammability:

Spontaneously flammable gas (195).

CHROMYL CHLORIDE

Mol. Wt.:
154.90

Formula:
 CrO_2Cl_2

Synonyms:
Chromium oxychloride

M.P.:
-96.5°C (79)

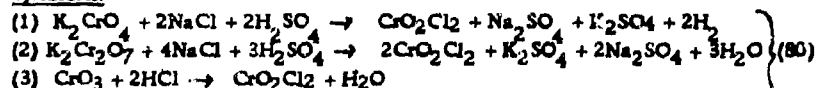
Characteristics:
Liquid -dark red (79)

V.P.:
2020 (195)

d./sp. gr.:
1.911 (79)

B.P.:
117°C (79)

Synthesis:



Unique conditions, reaction products:

Forms a smoke with atmospheric moisture (80).

Solubility:

d. hot and cold H_2O , alcohol; s. ether, CH_3COOH (79)

Thermodynamic properties:

standard heat of formation (at 25°C) (liq): -135.7 kcal/mol (79)

LITHIUM HYPOCHLORITE (With > 39% available chlorine)

Mol. Wt.:
58.39

Formula:
 LiOCl

Characteristics

solid - white powder (54)

Unique conditions, reaction products

Decomposes in H₂O₂ with heat or sun may decompose spontaneously rupturing containers, the vapors evolved may ignite spontaneously in air (54).

SODIUM HYPOCHLORITE

Mol. Wt.:

74.45

Formulas

NaOCl

M.P.:

d. (195)

B.P.:

d. (195)

Synthesis

$2\text{NaOH} + \text{Cl}_2 + 4\text{H}_2\text{O} \rightarrow \text{NaClO} \cdot 5\text{H}_2\text{O} + \text{NaCl}$ (80)

Unique conditions, reaction products

Decomposes explosively in air due to CO₂ (80).

Thermodynamic properties

standard heat of formation -82.7 kcal/mol (79).

PHOSPHORUS TRICHLORIDE

Mol. Wt.:

137.33

Formulas

PCl₃

M.P.:

-112°C (79)

Characteristics

Liquid - colorless fuming (79)

V.P.:

10021 (195)

d./sp.gr.:

5.4 (79)

B.P.:

75.5749 (79)

V.d.:

4.75 (195)

n_D¹⁴

1.516 (79)

Toxicity

Vapors irritating, can cause severe burns (190); threshold limit .5 ppm (195).

Synthesis

Pass stream of chlorine gas over melted phosphorus, heated red phosphorus, or through carbon disulfide solution of yellow phosphorus, obtain liquid trichloride by fractional distillation (214).

Solubility:

d. hot and cold H₂O; s. ether, C₆H₆, chloroform, CS₂, CCl₄ (79).

Handling

Keep cool, away from water, steam, acids, and oxidizing materials (195).

Thermodynamic properties

standard heat of formation -73.22 kcal/mol
free energy of formation (at 25°C) -68.42 kcal/mol
standard entropy 74.49 e.u. } (79)

Military and industrial uses

PCl₃ is used as a chlorinating agent in the manufacture of synthetic organic chemicals, specifically to replace hydroxyl groups by chlorine (214).

Flammability

Contact with H₂O may cause fire (190).

PHOSPHORUS PENTACHLORIDE

Mol. Wt.:

208.24

Formula:

PCl₅

Synonyms:

Phosphorus perchloride
Phosphorus chloride

M.P.:

c. 166.8°C (79)

Characteristics:

Solid yellow white
tetragonal (79)

V.P.:

155.5 (195)

d./sp. gr.:

4.65²⁹⁶ (79)

B.P.:

sublimes 162°C (79)

Synthesis

Pass stream of chlorine gas over melted phosphorus, heated red phosphorus, or through a CS₂ solution of yellow phosphorus (excess treatment with chlorine) (214).

Unique conditions, reaction products

Moisture hazardous, decomposes with H₂O to yield heat (27).

Solubility

d. cold H₂O; s. CS₂ or CCl₄ (79)

Thermodynamic properties

standard heat of formation -95.35 kcal/mol
free energy of formation (at 25°C) -77.59 kcal/mol
standard entropy 84.3 e.u. } (79)

Military and industrial uses

Catalyst in manufacture of acetyl cellulose, for replacing hydroxyl-groups by chlorine, particularly for converting acids into acid chlorides (214).

PHOSPHORUS OXYCHLORIDE

Mol. Wt.:

153.33

Formula:

POCl₃

M.P.:
2°C (79)

Characteristics
Liquid - colorless, fuming (79)

d./sp. gr.:
1.675 (79)

B.P.:
105.3°C (79)

n_D²⁰:
1.46025.1 (79)

Unique conditions, reaction products
Hydrolyzes violently with H₂O (217).

Solubility:
d. cold and hot H₂O, alcohol, acids (79)

Thermodynamic properties

	<u>gas</u>	<u>liquid</u>
standard heat of formation:	-141.5 kcal/mol	
free energy of formation (at 25°C):	-130.3 kcal/mol	
standard entropy:	77.59 e.u.	
heat of vaporization:		8.06 kcal/mol
critical temperatures:		329°C
troutons constants:		21.3 cal/°K
surface tension (at 25°C):		31.6 dynes/cm

(79) (132)

TRIFLUORO PHOSPHANE SULFIDE

Mol. Wt.:
120.04

Formula:
(S)PF₃

M.P.:
-148.8°C (226)

Characteristics
Gas (226)

B.P.:
d. -52.3°C (226)

Solubility:
d. H₂O; s. ether; i. organic solvents (226)

Flammability:
Spontaneously flammable (226).

SULFURYL CHLORIDE

Mol. Wt.:
134.97

Formula:
SO₂Cl₂

M.P.:
-54.1°C (79)

Characteristics
Liquid - colorless (79)

d./sp. gr.:
1.667²⁰₄ (79)

B.P.:
69.1°C (79)

n_D²⁰:
1.444 (79)

Unique conditions, reaction products

With moisture in air yields smoke; decomposes with moisture forming H_2SO_4 and HCl (171).

Solubility:

d. hot and cold H_2O ; s. C_6H_6 , CH_3COOH (79)

Thermodynamic properties

standard heat of formation (liq): -49.2 kcal/mol (79)

Military and industrial uses

Smoke producer in World War II; also used with certain toxic gases to render them visible (171).

TETRABROMOSILANE

Mol. Wt.:

347.72

Formula:

$SiBr_4$

M.P.:

5.4°C (79)

Characteristics

Solid - cubic
Liquid - fuming (79)

d./sp. gr.:

(liq) 2.7715²⁵ (79)
(sol) 3.292 -79 (79)

B.P.:

154°C (79)

V.d.:

2.82 (195)

Synthesis

$Si + 2Br_2 \rightarrow SiBr_4$ (80)

Unique conditions, reaction products

Reacts with H_2O to yield heat and fumes (195).

Solubility:

d. hot and cold H_2O , H_2SO_4 (79)

Thermodynamic properties

standard heat of formation (liq): -95.1 kcal/mol (79)

SILICON CHLORIDE

Mol. Wt.:

169.90

Formula:

$SiCl_4$

M.P.:

-70°C (79)

Characteristics

Liquid - colorless fuming (79)

d./sp. gr.:

(liq) 1.483²⁰ (79)
(sol) 1.90-97 (79)
(gas) >.59 (79)

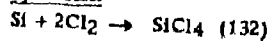
B.P.:

57.57°C (79)

Toxicity:

High (acute local) as irritant, on ingestion, and on inhalation (195).

Synthesis



Unique conditions, reaction products

Fumes heavily upon exposure to air (80).

Solubility:

d. hot and cold H_2O , alcohol (79)

Thermodynamic properties

	gas	liquid	} (79)
standard heat of formation	-145.7 kcal/mol	-153.0 kcal/mol	
standard free energy of formation	-136.2 kcal/mol	-136.9 kcal/mol	
standard entropy	79.2 e.u.	37.2 e.u.	

Military and industrial uses

Used as smoke screens in warfare and in the preparation of pure silicon (132).

TRIBROMOSILANE

Mol. Wt.:
268.9

Formula:
 SiHBr_3

Synonyms:
Silicobromoform

M.P.:
-73.5°C (195)

Characteristics:
Liquid - mobile,
inflammable (195)

Dipole moment:
.79 (132)

d./sp. gr.:
2.717₄ (195)

B.P.:
112°C (195)

V.P.:
8.8⁰ (195)

Toxicity:

Readily hydrolyzes to liberate HBr , a powerful irritant (195).

Synthesis



Solubility:

d. hot and cold H_2O , NH_3 (79)

Flammability:

Spontaneously flammable in air (195).

TRICHLOROSILANE

Mol. Wt.:
135.45

Formula:
 SiHCl_3

Synonyms:
Silicochloroform

M.P.:i

-126.5°C (79)

-134°C (195)

Characteristics

Liquid - colorless (79)

d./sp. gr.:i

1.34 (79)

B.P.:i

33758 (79)

Dipole moment:

.97 (132)

n_D²⁰

1.4020 (132)

Viscosity:

.397 cp (at 0°C) (132)

n_D²⁵

1.3983 (132)

V.d.:i

4.7 (195)

Toxicity:

Moderate (acute local) as irritant on inhalation; moderate (acute systemic) on ingestion, inhalation (195)

Synthesis $\text{Si} + 3\text{HCl} \rightarrow \text{SiHCl}_3 + \text{H}_2$ (80)Unique conditions, reaction products

Violent reaction with water (27).

Ignition temperatures

flash points < 20°F (195)

Solubility:d. hot and cold H₂O; s. CS₂, CCl₄, chloroform, C₆H₆ (79)Flammability:

Spontaneously flammable in air (195).

BROMO SILANE

Mol. Wt.:i

111.02

FormulasSiH₃BrM.P.:i

-94°C (79)

Characteristics

Gas - colorless (79)

d./sp. gr.:i1.72-80
1.533⁰ (79)B.P.:i

1.9°C (79)

Flammability:

Explodes in air (79)

SILICON HEXACHLORIDE

<u>Mol. Wt.:</u> 268.89	<u>Formula:</u> Si_2Cl_6	<u>Synonym:</u> Hexachlorodisilane
<u>M.P.:</u> -1°C (79)	<u>Characteristics:</u> Liquid - colorless (79)	<u>V.d.:</u> 9.29 (195)
<u>d./sp. gr.:</u> 1.58 ⁰ (79)	<u>B.P.:</u> 145.768 (79)	<u>$\frac{n_D^{18}}{D^4}$</u> 1.4748 (79)

Synthesis

Pass vapor of silicon tetrachloride over white-hot silicon (contained in a porcelain tube), by cooling the products rapidly Si_2Cl_6 is separable by fractional distillation (131).

Solubility:

d. hot and cold H_2O , alcohol (79)

Flammability:

Spontaneously flammable liquid; vapor ignites spontaneously in air (27).

DISILYAMINO DICHLOROBORANE

<u>Mol. Wt.:</u> 157.93	<u>Formula:</u> $(\text{SiH}_3)_2\text{NBHCl}_2$	
<u>M.P.:</u> d. 62°C (226)	<u>Characteristics:</u> Solid (226)	<u>V.P.:</u> 25.22 (226)

Flammability:

Spontaneously flammable (226).

ANTIMONY PENTACHLORIDE

<u>Mol. Wt.:</u> 299.02	<u>Formula:</u> SbCl_5	
<u>M.P.:</u> 2.8°C (79)	<u>Characteristics:</u> Liquid - white (79) Solid - monoclinic (79)	<u>V.P.:</u> 122.7 (195)
<u>d./sp. gr.:</u> 2.336 ²⁰ (79)	<u>B.P.:</u> 79.22 (79)	<u>$\frac{n_D^{14}}{D^4}$</u> 1.601 (79)

Synthesis

Pass chlorine into molten SbCl_3 (132).

Unique conditions, reaction products

Gives white smoke with atmospheric moisture (167).

Solubility:

d. hot and cold H₂O; s. HCl, tartaric acid, methyl dichloride (79)

Thermodynamic properties:

standard heat of formation: $\overset{948}{-93.9 \text{ kcal/mol}}$ $\overset{\text{liquid}}{-104.8 \text{ kcal/mol}}$ (79)

TIN TETRACHLORIDE

Mol. Wt.:
260.50

Formula:
SnCl₄

M.P.:
-33°C (79)

Characteristics:
liquid - colorless or
solid - cubic (79)

d./sp. gr.:
2.28 (79)

B.P.:
114°C (79)

$\overset{n}{D_D}$
1.512 (79)

Synthesis:

Formed by direct chlorination of metallic tin (172).

Unique conditions, reaction products:

Produces smoke with moisture [SnCl₄ + 4H₂O → Sn(OH)₄ + 4HCl] (19).

Solubility:

s. cold H₂O, ether; d. hot H₂O (79)

Thermodynamic properties:

standard heat of formation: $\overset{\text{Liquid}}{-179.3 \text{ kcal/mol}}$
standard free energy of formation: -161.2 kcal/mol
standard entropy: 60.4 e.u. } (79)

TITANIUM DIBROMIDE

Mol. Wt.:
207.72

Formula:
TiBr₂

M.P.:
d. > 500°C (79)

Characteristics:
Solid - black powder (79)

d./sp. gr.:
4.31 (79)

Solubility:

s. cold H₂O with evolution of H₂ (79)

Thermodynamic properties

standard heat of formation - 85 kcal/mol (79)

Flammability:

Spontaneously flammable (240); ignites in moist air (80)

TITANIUM DICHLORIDE

Mol. Wt.:

118.81 (79)

Formulas

TiCl₂

Synonyms

Titanium dichloride

M.P.:

Sublimes H₂ (79)

Characteristics

Solid - light brownish
black, hexagonal,
deliquescent (79)

d./sp. gr.:

3.13 (79)

B.P.:

d. 475 (in vacuum) (79)

Synthesis

TiCl₄ + Ti → 2TiCl₂ (80)

Solubility:

d. cold H₂O; s. alcohol; l. ether, chloroform CS₂ (79)

Thermodynamic properties

standard heat of formation:

crystalline

-114 kcal/mol (79)

Flammability:

Ignites in moist air (80); shines like a red-hot iron in H₂O and dissolves with evolution of H₂ (131).

TITANIUM TRICHLORIDE

(Anhydrous)

Mol. Wt.:

154.26 (79)

Formulas

TiCl₃

M.P.:

d. 440°C (79)

Characteristics

Solid - dark violet
deliquescent (79)

d./sp. gr.:

2.64 (79)

B.P.:

600/0.8 (79)

Synthesis

- | | |
|--|--------|
| (1) 2TiCl ₄ + H ₂ → 2TiCl ₃ + 2HCl | } (80) |
| (2) 3TiCl ₄ + Ti → 4TiCl ₃ | |
| (3) 3TiCl ₄ + Sb → 3TiCl ₃ + SbCl ₃ | |
| (4) Reduce TiCl ₄ with H ₂ in an electric arc | |

Solubility:

s. cold H₂O, hot H₂O; v. s. alcohol; s. HCl; i. ether (79)

Thermodynamic properties:

standard heat of formation crystalline
-165 kcal/mol (79)

Military and industrial uses:

Used as reducing agent; in organic synthesis, as co-catalyst for polyolefin polymerization; in organo-metallic synthesis involving titanium (190).

Flammability:

Spontaneously flammable in air (124).

TITANIUM TETRACHLORIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
189.71	TiCl ₄	Titanic chloride
<u>M.P.:</u>	<u>Characteristics:</u>	<u>V.F.:</u>
-25°C (79)	Liquid - light yellow (79)	1021.3 (195)
<u>d./sp. gr.:</u>	<u>B.P.:</u>	<u>n_D²⁰:</u>
(liq) 1.726	136.4°C (79)	<u>D₄</u>
(sol) 2.06 ⁻⁷⁹ (79)		1.61 (79)

Toxicity:

High (acute local) as irritant, on inhalation; high (chronic local) on inhalation; can cause severe burns, do not wash with H₂O (severe burns due to formation of HCl) (195).

Synthesis:



Unique conditions, reaction products:

Produces white fumes in moist air; liberates heat and HCl on contact with moisture (195); readily forms adducts with NH₃, pyridine and non metal chlorides (89).

Solubility:

s. cold H₂O; d. hot H₂O; s. dilute HCl, alcohol (79)

Thermodynamic properties:

standard heat of formation: 753.2 ± 2.9 kg/mol (-182.4 ± .7 kcal/mol) (101)
triple point temperature: 249.045 ± .010°K (141)

Military and industrial uses:

Chemical warfare symbol is FM, called by Germans "F-stoff", produces smoke in air, in combination with NH₃ vapor gives a denser smoke (19, 20).

TITANIUM DIOXIDE

Mol. Wt.:
301.71

Formula:
 TiO_2

M.P.:
600°C (79)

Characteristics:
Solid - black hygroscopic (79)

d./sp. gr.:
4.99 (79)

B.P.:
1000°C (79)

Synthesis

Reduce $TiCl_4$ to TiI_2 by silver or mercury. Arrange two porcelain boats in a porcelain tube (the anterior one containing Hg and the posterior one TiI_4), raise the temperature to dull redness while a current of hydrogen is passed through the tube. A sublimate of mercuric iodide and unchanged TiI_4 is formed in the cool receiver and TiI_2 is formed near the exit of the tube (131).

Solubility:

d. cold H_2O , alkaline solvents; s. concentrated HF, concentrated HCl (79)

Thermodynamic properties

	<u>crystalline</u>
standard heat of formation	-61 kcal/mol (79)

Flammability:

Ignites in moist air (80).

VANADYL CHLORIDE

Mol. Wt.:
173.30

Formula:
 $VOCl_3$

Synonyms:
Vanadium oxytrichloride

M.P.:
-77 ± 2°C (79)

Characteristics:
Liquid - yellow (79)

d./sp. gr.:
1.82⁹ (79)

B.P.:
126.7°C (79)

Synthesis

- (1) $V_2O_5 + 3SOCl_2 \rightarrow 2VOCl_3 + 3SO_2$ (80)
- (2) $V_2O_3 + 3Cl_2 \rightarrow 2VOCl_3 + 1/2O_2$ (80)

Unique conditions, reaction products

Forms orange smoke with atmospheric moisture; smoke density is increased by addition of $TiCl_4$; reacts with H_2SO_4 to yield $VOCl_3 \cdot SO_3$ which with moisture yields dense white smoke (167-168).

Solubility:

s. d. cold H_2O ; s. alcohol, ether, acetic acid, Br_2 (79).

Thermodynamic properties

standard heat of formations crystalline
-172 kcal/mol (79)

ZIRCONIUM DIBROMIDE

Mol. Wt.:
251.05

Formula:
 $Zr(Br)_2$

Synonyms:
Dibromo zircon

M.P.:
d. 350°C (226)

Characteristics:
Solid - black powder (226)

Toxicity:

Dangerous upon decomposition, toxic fumes of bromide are emitted (195).

Unique conditions, reaction products:

Vigorous reaction with oxidizing materials (195).

Solubility:

d. cold H_2O (226)

Thermodynamic properties

standard heat of formations crystalline
-120 kcal/mol (79)

Flammability:

Spontaneously flammable (226).

(g) HYDRIDES

ALUMINUM BORCHYDRIDE

Mol. Wt.:

71.54

Formulas:

$\text{Al}(\text{BH}_4)_3$

Synonyms:

Aluminum tri-
(tetrahydroborane)

M.P.:

71.54

Characteristics:

Liquid - colorless (226)

V.P.:

$\log P = 7.808 - 1565/T$
1200, 25717 (226)

d./sp. gr.:

.5610, .53310, .54420,
.53729.4 (226)

B.P.:

44.5°C (226)

Synthesis:

(1) $(\text{CH}_3)_3\text{Al} + 2\text{B}_2\text{H}_6 \rightarrow (\text{CH}_3)_3\text{B} + \text{Al}(\text{BH}_4)_3$ (70)

(2) $2\text{AlH}_3 + 3\text{B}_2\text{H}_6 \rightarrow 2\text{Al}(\text{BH}_4)_3$ (70)

(3) $\text{LiAlH}_4 + \text{CB}_2\text{H}_6 \rightarrow \text{LiBH}_4 + \text{Al}(\text{BH}_4)_3$ (70)

Unique conditions, reaction products:

Forms addition compounds readily with amines (226).

Solubility:

d. H_2O (explodes); s. organic solvent (226).

Thermodynamic properties:

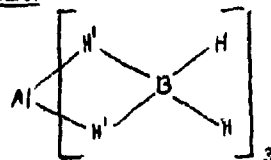
heat of vaporization: 7160 cal/mol (226)

heat of combustion: 13760 cal/g (226)

Flammability:

Vapor detonates spontaneously and violently on contact with air containing moisture (196).

Structures:



$\text{Al} - \text{B} = 2.15\text{\AA}$

$\text{Al} - \text{H}' = 2.1\text{\AA}$

$\text{B} - \text{H}' = 1.28\text{\AA}$

$\text{B} - \text{H} = 1.21\text{\AA}$

} (174)

ALUMINUM HYDRIDE

Mol. Wt.:

120.0

Formulas:

$(\text{AlH}_3)_x$

M.P.:

d. 100°C (226)

Characteristics:

Solid - gray white (226)

Synthesis

- (1) $3\text{LiAlH}_4 + \text{AlCl}_3 \rightarrow 4(\text{AlH}_3) + 3\text{LiCl}$ (117)
(2) $3\text{LiH} + \text{AlCl}_3 \xrightarrow{\text{ether}} \text{AlH}_3 + 3\text{LiCl}$ (117)

Solubility

d. H_2O , alcohol, air; s. ether (226)

Thermodynamic properties

heat of formation (at 298°K) (gas): 18 ± 10 kcal/mol
entropy (at 298°K): 47.7 e.u.
free energy of formation (at 298°K): 20.9 kcal/mol } (119)

Flammability

Spontaneously flammable in air or O_2 (118).

TRISILYL ARSINE

Mol. Wt.:

168.25

Formula:

$\text{As}(\text{SiH}_3)_3$

B. P.:

d. 25°C (226)

Characteristics

Liquid (226)

V. P.:

1.70 (226)

Solubility

d. H_2O (226)

Flammability

Spontaneously flammable (226).

TRIBROMO BORINE ARSINE

Mol. Wt.:

328.54

Formula:

BBr_3AsH_3

M. P.:

7°C (226)

Characteristics

Liquid (226)

B. P.:

d. 40°C (226)

Flammability

Spontaneously flammable (226).

DIBROMO BORINE PHOSPHINE

Mol. Wt.:

284.59

Formula:

BBr_3PH_3

Characteristics

Solid - white amorphous (226)

Flammability

Spontaneously flammable (226).

DIBORANE

Mol. Wt.:
26.67

Formula:
 B_2H_6

Synonyms:
Boron hydride
Borvethane

M.P.:
-165.5°C (226)

Characteristics:
Gas - colorless
sickly sweet odor (195)

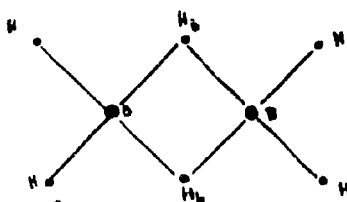
V.P.:
224-112 (195)

d./sp.gr.:
(liq) .447-112 (195)
(sol) .577-183 (195)

B.P.:
-92.5 (226)

V.d.:
.96 (142)

Structure:



$B - H = 1.87 \pm .010 \text{ \AA}$
 $B - H_b = 1.334 \pm .027 \text{ \AA}$
 $B - B = 1.77 \pm .013 \text{ \AA}$ (124)
H is the terminal H atom
 H_b is the bridge H atom

Toxicity:

High as irritant; is a lung irritant and can cause pulmonary edema; ACGIH accepted tolerance level: 1 ppm (1 mg/m³) of air (195).

Synthesis:

- (1) $6LiH + 8BF_3 \cdot O(C_2H_5)_2 \rightarrow B_2H_6 + 6LiBF_4 + 8(C_2H_5)_2O$ (80)
- (2) $3LiBH_4 + 4BF_3 \cdot O(C_2H_5)_2 \rightarrow 2B_2H_6 + 3LiBF_4 + 4(C_2H_5)_2O$ (80)
- (3) $6NaH + 2BCl_3 + 6AlCl_3 \text{ benzene} \rightarrow B_2H_6 + 6NaAlCl_4$ (16)
- (4) heat 2gs of a pearl shaped mixture of boron and sodium metaborate in the molecular ratio 3 : 1 with a hydrogen stream flowing through the reaction container at the rate of 2 l/min at atmospheric pressure and 1000°C (2)
- (5) $HCHO + 2BBr_3 \xrightarrow[Cu]{400^\circ C} B_2H_6 + HBr + CO + \text{side products}$ (21)

Unique conditions, reaction products:

When heated to decomposition emits dangerous boron oxide fumes, yields hydrogen when in contact with water or steam (195). Diborane may be spontaneously flammable due to the presence of pentaborane as a decomposition product (236). It reacts spontaneously with chlorine and forms spontaneously flammable hydrides with aluminum and lithium (143).

Ignition temperature:

Autoignition temperature: 100 - 125°F (142)
Flammability limits .9 - 98% (142)

Solubility:

sl. s. cold H_2O (d. to H_3BO_3 and H_2); : NH_4OH , concentrated H_2SO_4 (80)

Handling

Protect from physical damage; keep refrigerated (under 68°F), keep well ventilated, containers should be clean, dry and free of oxygen, store away from halogens and oxidizing agents, protect from sparks, open flames and other heat sources (142).

Thermodynamic properties

dipole moment: 0 debye (179)
heat of combustion: 481.9 kcal/mol (221)
heat capacity (at 25°C): 13.30 cal/°mol (221)
heat of vaporization: 3.685 cal/mol (179)
heat of formation: -44 ± 3 kcal/mol (179)
critical temperature: 16.7 ± .02°C (179)
critical pressure: 581 ± 5 psia (179)
entropy (at 25°C): 55.34 cal/°mol (221)
free energy of formation (at 25°C): 19.78 kcal/mol (221)

Military and industrial uses

Used in organic synthesis for hydrating double bonds and obtaining cis addition (132); used as fuel in air breathing engines and rockets, as a reducing agent and in the synthesis of organic boron compounds (190).

Flammability

Spontaneously flammable in moist air at room temperature (142).

DISILYAMINO DIBORANE

Mol. Wt.:

102.92

Formula:

B₂H₅N(SiH₃)₂

Characteristics:

Liquid - straw (226).

M.P.:

-68.5°C (226)

B.P.:

54°C (226)

V.P.:

7.974-1669/T; 162° (226)

Solubility:

s. organic solvent; d. H₂O (226)

Thermodynamic properties

heat of vaporization (at 54°C): 7640 cal/mol (226)

Flammability:

Spontaneously flammable (226).

TETRABORANE

Mol. Wt.:

53.96

Formula:

B₄H₁₀

Synonyms:

dihydrotetraborane

borobutane

tetraboron decahydride

boron hydride

M.P.:

-120°C (226)

Characteristics:

Gas - colorless (226)

d./sp. gr.:

.56-35 (226)

B.P.:

16°C (226)

V.P.:

5806, 3280 (79)

Toxicity:

High (acute local) on inhalation (195); high (acute systemic) on inhalation (195).

Synthesis

Precipitated from reaction of magnesium boride with HCl or phosphoric acid (132).

Unique conditions, reaction products

Forms boric acid and hydrogen on reacting with H_2O ; forms tetraammonate from NH_3 (132).

Solubility:

d. H_2O (226), alcohol (79)

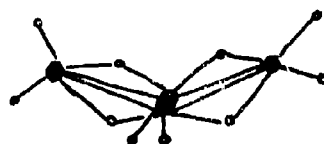
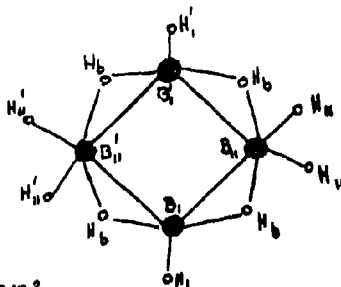
Thermodynamic properties

heat of vaporization 6.47 kcal/mol (226)

Flammability:

Spontaneously flammable in air (226).

Structures



$B_1 - B_{11} = 1.842 \text{ \AA}$
 $B_1 - B_{1'} = 1.712 \text{ \AA}$
 $B_{11} - B_{1''} = 2.800 \text{ \AA}$
 $B - H = 1.10 \text{ \AA}$ (174)
 $B_1 - H_{1'} = 1.16 \text{ \AA}$
 $B_{11} - H_{1''} = 1.37 \text{ \AA}$

PENTABORANE (Stable)

Mol. Wt.:

63.13

Formula:

B_5H_9

Synonyms

Pentaboron anhydride

M.P.:

-46.82°C (79)

Characteristic

Gas - colorless, bad odor

Liquid - colorless, bad odor

V.P.:

66° (195)

d./sp. gr.:

.66° (79)

n_D^{25}

1.4445 (49)

V.d.:

2.2 (195)

B.P.:

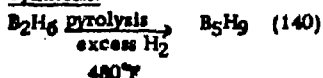
58.4°C (79)

Toxicity:

Maximum tolerance .005 ppm (.01 mg/m³) (195); an hour after a 1½ minute exposure to pentaborane during a disposal operation the men experienced psychomotor function difficulties, memory

blocking, lack of coordination, feelings of detachment ("classic" symptoms of boron toxicosis) irrationality
loss followed for four days (9).

Synthesis



Unique conditions, reaction products

Hydrolyzes slowly in H_2O at room temperature, will react with any organic compound containing a reducible functional group, reacts with hydrogen and other amines, react with ClF_3 to yield hypergolic ignition and intense fireballs (152); large explosion with hydrazine (189).

Solubility

- d. cold H_2O : without reaction in hydrocarbon solvents (e.g., kerosene, hexane, benzene, toluene);
- s. in oxygenated or halogenated solvents — but forms shock sensitive mixture (152).

Ignition temperatures

- Spontaneously ignites at 65.5°C (67)
- Lean limit of spontaneous ignition: 14% (vol) at 1 atmosphere and 55% at .1 atmosphere (188)
- Rich limit of spontaneous ignition: not determined but 75% ignites at 5 cm mercury (183)

Handling

Can be stored for at least 3 years in a clean moisture free vessel under an inert atmosphere (140).

Thermodynamic properties

- heat of combustion: 1003 kcal/mol (221)
- heat of formation (at 25°C) (gas): 15.02 kcal/mol (221)
- heat of formation (liq): 7.72 kcal/mol (221)
- free energy of formation (at 25°C) (gas): 39.32 kcal/mol (221)
- free energy of formation (liq): 38.56 kcal/mol (221)
- entropy (at 25°C) (gas): 65.95 cal/ $^\circ\text{mol}$ (221)
- entropy (liq): 44.03 cal/ $^\circ\text{mol}$ (221)
- heat capacity (at 25°C) (gas): 23.52 cal/ $^\circ\text{mol}$ (221)
- heat capacity (liq): 36.12 cal/ $^\circ\text{mol}$ (221)
- dipole moment (at -80.2°F): 4.54 debye (105)
- heat of vaporization (at -72.4°F): 13,860 Btu/lb mol (105)

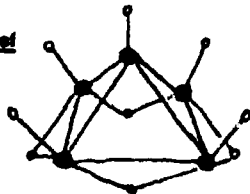
Military and industrial uses

Liquid rocket fuel (140).

Flammability

Spontaneously flammable (195); pyrophoric tendencies may be due to contamination by diborane (28); high humidity decreases likelihood of B_5H_9 air reaction (49).

Structure



$$\begin{aligned} \text{B} - \text{B} &= 1.66 - 1.77 \text{\AA} \\ \text{B} - \text{H} &= 1.20 - 1.35 \text{\AA} \end{aligned} \quad (49)$$

PENTABORANE
(Unstable)

Mol. Wt.:
65.2

Formulas:
 B_5H_{11}

Synonyms:
Dihydropentaborane

M.P.:
-123°C (132)

Characteristics:
Liquid - colorless, turns
yellow on standing (195)

V.P.:
52.8°; 7.2-33.4 (226)

B.P.:
63°C (195)

Toxicity:

Tolerance: .005 ppm (.01 mg/m³ air) (195)

Unique conditions, reaction products

On standing for a long period of time or heating, it produces diborane, tetraborane, hydrogen, penta-
borane, decaborane and brown nonvolatile liquids and solids; hydrolyzes in water to boric acid and
hydrogen, reacts with ammonia to form tetraammoniate (132).

Solubility:

d. alcohol, air (226)

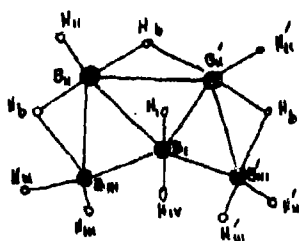
Thermodynamic properties

heat of vaporization: 7.61 kcal/mol (226).

Flammability:

Spontaneously flammable (226).

Structure:



$B_1 - B_{11} = 1.72\text{\AA}$
 $B_1 - B_{111} = 1.87\text{\AA}$
 $B_{11} - B_{111} = 1.76\text{\AA}$
 $B_{11} - B'_{11} = 1.77\text{\AA}$
 Ave B - H = 1.10\text{\AA}
 Ave B - H_b = 1.22\text{\AA}
 $B_1 - H_w = 1.09\text{\AA}$
 $B_{111} - H_{1V} = 1.72\text{\AA}$
 Angle $B_{111} - B_{11} - B'_{11}$ is 112°

(174)

HEXABORANE

Mol. Wt.:
75.00

Formulas:
 B_6H_{10}

Synonyms:
Boron hydride
Hexaboron decahydride

M.P.:
-65°C (226)

Characteristics:
Liquid - colorless (226)

V.P.:
7° (226)

d./sp. gr.:
.69 (226)

B.P.:
110°C (226)

V.d.:
2.6 (195)

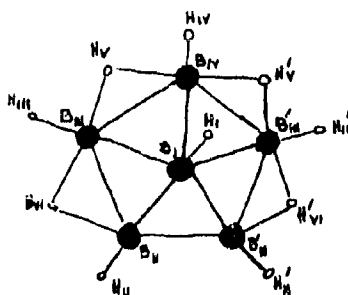
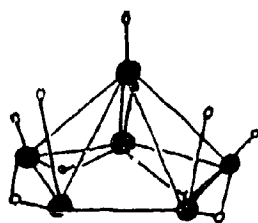
Solubility:

d. H_2O , alcohol (226)

Flammability:

Spontaneously flammable (226).

Structure:



$$\left. \begin{aligned} B_1 - B_{11} &= 1.795 \pm .010 \text{ \AA} \\ B_1 - B_{111} &= 1.753 \pm .009 \text{ \AA} \\ B_1 - B_{1V} &= 1.740 \pm .014 \text{ \AA} \\ B_{11} - B'_{11} &= 1.596 \pm .012 \text{ \AA} \\ B_{11} - B_{111} &= 1.737 \pm .010 \text{ \AA} \\ B_{111} - B_{1V} &= 1.794 \pm .009 \text{ \AA} \\ B_1 - H_1 &= 1.25 \pm .06 \text{ \AA} \\ B_{11} - H_{11} &= 1.28 \pm .05 \text{ \AA} \\ B_{11} - H_{V1} &= 1.36 \pm .04 \text{ \AA} \\ B_{111} - H_{111} &= 1.18 \pm .04 \text{ \AA} \\ B_{111} - H_{V1} &= 1.31 \pm .04 \text{ \AA} \\ B_{111} - H_V &= 1.48 \pm .05 \text{ \AA} \\ B_{1V} - H_{1V} &= 1.14 \pm .06 \text{ \AA} \\ B_{1V} - H_V &= 1.22 \pm .06 \text{ \AA} \end{aligned} \right\} (174)$$

DIHYDROHEXABORANE

Mol. Wt.:

77.02

Formulas:

B_6H_{12}

M.P.:

-90°C (226)

Characteristics:

Liquid - colorless,
unstable (226)

B.P.:

d. 20°C (226)

Solubility:

d. alcohol; s. organic solvent (226)

Flammability:

Spontaneously flammable (226).

DECABORANE

Mol. Wt.:

122.22

Formulas:

$B_{10}H_{14}$

Synonyms:

Boron hydride

Decaboron tetracahydride

M.P.:

99.5°C (226)

Characteristics:

Solid - white, crystal (226)

d./sp. gr.:

.9425 (226)

B.P.:

213°C (226)

V.P.:

19100 (226)

Toxicity:

High as irritant, and on inhalation tolerance .05 ppm (.3 mg/m³) air (195).

Solubility:

l. s. cold H₂O; d. hot H₂O; s. alcohol, ether, benzene (79)

Thermodynamic properties

standard heat of formations 8 kcal/mol (79)

heat of combustions 1950 kcal/mol (79)

free energy of formations

standard entropy

heat capacity

gas

71 kcal/mol

15.09 e. u.

40.0 cal/°mol

liquid

65 kcal/mol

42.20 e. u.

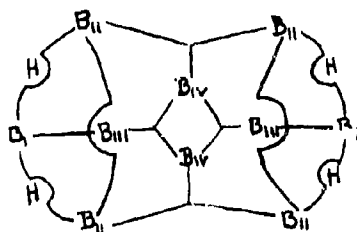
52.09 cal/°mol

} (79)

Flammability:

Spontaneously flammable in air or O₂ (143).

Structure:



Each B atom is two center bonded to a hydrogen atom (not shown in diagram) (174)

BARIUM HYDRIDE

Mol. Wt.:

139.38

Formula:

BaH₂

M.P.:

d. 675°C (79)

Characteristics:

Solid - gray crystal lumps (79)

d./sp. gr.:

4.21 (226)

B.P.:

1400°C (79)

Unique conditions, reaction products:

Vigorous reaction with H₂O (91)

Solubility:

d. cold H₂O to Ba(OH)₂, d. acid (79)

Thermodynamic properties

heat of formations 40.96 kcal/mol (226)

free energy of formations -31.6 kcal/mol (32)

entropy (at 208°C) 16 cal/°mol (32)

Military and industrial uses

Used as a reducing agent and as condensation and reducing agent for organic reactions (91).

Flammability:

If finely powdered spontaneously ignites in moist air, possible also to spontaneously ignite in dry air (91).

BERYLLIUM BOROHYDRIDEMol. Wt.:

38.72

Formulas: $\text{Be}(\text{BH}_4)_2$ Synonyms:

Beryllium bis(tetrahydroboron)

M.P.:

d. 125°C (226)

V.P.:

.5° (226)

Unique conditions, reaction products:

Vigorous reaction with water and other reducing agents (226); reacts with water to yield heat and hydrogen (195); explosive reaction with H_2O or O_2 (220).

Solubility:

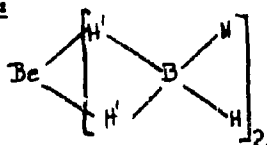
s. organic solvents, including non-polar solvents such as benzene (226).

Thermodynamic properties:

heat of sublimation	14,820 cal/g mol	} (103)
heat of vaporization	14,810 cal/mol	
heat of formation	98 kcal/mol	
heat of combustion	16.7 kcal/mol	

Flammability:

Spontaneously flammable in air (226).

Structures:

Be - B = 1.74Å	} (174)
Be - H' = 1.83Å	
B - H' = 1.28Å	
B - H = 1.22Å	

BERYLLIUM HYDRIDEMol. Wt.:

11.03

Formulas: BeH_2 M.P.:

d. 125°C (226)

Characteristics:

Solid - white (226)

Synthesis:

(1) $\text{Be}(\text{CH}_3)_2 + \text{LiAlH}_4 \xrightarrow{\text{Et}_2\text{O}} \text{BeH}_2 + \text{LiAlH}_2(\text{CH}_3)_2$ (ether of composition not removable) (134)
 (2) $\text{Be}(\text{C}_4\text{H}_9)_2 \xrightarrow{\Delta} \text{BeH}_2 + 2\text{C}_4\text{H}_8$ (134)

Unique conditions, reaction products:

Reacts with water, dilute acid, CH_3OH to yield H_2 (195).

Solubility:

i. ether, toluene, isopentane (226)

CALCIUM HYDRIDE

M.P.:

> 1000°C (226)

816°C in hydrogen (195)

Formulas

CaH_2

Characteristics

Solid - white crystals (226)

B.P.:

d. 1000°C (133)

d. 600°C (195)

d./sp. gr.:

1.9 (226)

Synthesis

Heat parent metal in hydrogen atmosphere at 200°-300°C (133); reduce lime in presence of hydrogen with magnesium (132).

Solubility:

d. with H_2O , lower alcohols, and carboxylic acids to form H_2 (132)

Thermodynamic properties

heat of formations 46.6 kcal/mol (226)

Military and industrial uses

To generate H_2 (1g CaH_2 in $\text{H}_2\text{O} \rightarrow 1\text{ l H}_2$ at STP), preparation of rare metals by reduction of their oxides, as a drying agent for liquids and gases (132).

Flammability:

Calcium hydride "less likely" to ignite in water than NaH , LiAlH_4 or NaAlH_4 , may have dust explosion if finely dispersed in air (133).

CERIUM (III) ALUMINOHYDRIDE

Mol. Wt.:

233.07

Formulas

$\text{Ce}(\text{AlH}_4)_3$

M.P.:

d. -80°C (13)

Synthesis

From the solid complex with LiEt ; treat the complex with LiAlH_4 near freezing point of the ether; a precipitate of $\text{Ce}(\text{AlH}_4)_3$ is yielded (13).

Flammability:

Spontaneously flammable (13).

CERIUM HYDRIDE

Mol. Wt.:

143.14

Formulas

CeH_3

Synonyms:

Trihydrocerine, cerous hydride

M.P.:
d. 1080°C (226)

Characteristics:
Solid - black powder (226)

V.P.:
.5450-500 (226)

d./sp. gr.:
5.5 (226)

Solubility:
d. air, H₂O (226)

Thermodynamic properties
heat of formation 42.26 kcal/mol (226)

Flammability:
Spontaneously flammable (226).

COBALT TRIPHOSPHINE

Mol. Wt.:
157.85

Formulas
Co(PH₂)₃

Flammability:
Spontaneously flammable (240).

CESIUM HYDRIDE

Mol. Wt.:
133.92

Formulas
CsH

M.P.:
decomposes (79)

Characteristics
Solid - white, cubic
crystalline (79)

d./sp. gr.:
2.7 (195)
3.41 (79)

Synthesis
Cs + 1/2H₂ → CsH (80)

Solubility:
d. hot and cold H₂O, alcohol; i. organic solvents (79)

Thermodynamic properties

	<u>gas</u>	<u>crystalline</u>
heat of formation	29.0 kcal/mol	-10.1 kcal/mol
free energy of formation	24.3 kcal/mol	-7.3 kcal/mol (at 9°C)
entropy:	51.25 cal/°mol	20.8 cal/mol (at 102 mm)

} (31)

Flammability:
Ignites in oxygen at room temperature (80).

COPPER ALUMINOHYDRIDE

Mol. Wt.:
94.52

Formula:
 CuAlH_4

M.P.:
d. -70°C (13)

Synthesis

Form a solid complex with LiBr then treat with LiAlH_4 near the freezing point of ether and a precipitate of aluminohydride is yielded (13).

Flammability:

Spontaneously flammable (13).

COPPERHYDRIDE

Mol. Wt.:
64.55

Formula:
 CuH

M.P.:
d. slowly $55^\circ\text{--}60^\circ\text{C}$ (103)

Characteristics
Red - brown (103)

d./sp. gr.:
6.38 (103)

Solubility:

i. cold H_2O ; d. hot H_2O , HCl (103)

Thermodynamic properties

standard heat of formation: 71 kcal/mol
standard free energy of formation: 64 kcal/mol
standard entropy: 46.89 cal/ $^\circ\text{mol}$ } (79)

Flammability:

Spontaneously flammable in air when dry (234).

GALLIUM HYDRIDE

Mol. Wt.:
135.49

Formula:
 Ga_2H_6

Synonyms
Digallene

M.P.:
 -21.4°C (226)

Characteristics
Liquid - colorless (226)

V.P.:
2.50, 700130 (226)

B.P.:
 139°C (extrapolated) (226)

Synthesis



Flammability

Probably spontaneously flammable (53).

GERMANIUM HYDRIDE

Mol. Wt.:

76.62

Formula:

GeH_4

Synonyms:

Germane

M.P.:

-165°C (79)

Characteristics:

Gas - colorless (79)

B.P.:

-88.5°C, d. 350°C (79)

d./sp. gr.:

1.523-1.42 (79)

Synthesis



Solubility:

l. hot and cold H_2O ; s. liquid NH_3 , NaOCl (79)

Thermodynamic properties

enthalpy -22.7 ± .5 kcal/mol (78)

heat of formation 21.6 ± .5 kcal/mol (78)

Flammability:

Decomposes in air often bursting into flames (80).

GERMANIUM HYDRIDE

Mol. Wt.:

151.25

Formula:

Ge_2H_6

Synonyms:

Digermane

M.P.:

-109°C (79)

Characteristics:

Liquid (79)

B.P.:

29°C (79)

d./sp. gr.:

1.98-1.09 (79)

Synthesis



Solubility:

d. cold H_2O ; s. liquid NH_3 (79)

Thermodynamic properties

heat of formations 38.7 ± 3 kcal/mol (78)

Flammability

Decomposes in air often bursting into flames (80).

GERMANIUM HYDRIDE

Mol. Wt.:
225.83

Formulas
 Ge_3H_8

Synonyms
Trigermana

M. P.:
 -105.6°C (79)

Characteristics
Liquid - colorless (79)

B. P.:
 110.5°C (d. 195°C) (79)

d./sp. gr.:
2.220 (79)

Synthesis

(1) $\text{GeMg}_2 + \text{HCl}(\text{aqueous}) \rightarrow \text{Ge}_3\text{H}_8 + \dots$ (80)

Solubility

i. hot and cold H_2O ; s. CCl_4 (79)

Flammability

Decomposes in air often bursting into flames (80).

SODIUM HYDRIDE

Mol. Wt.:
24.00

Formulas
 NaH

d./sp. gr.:
1.396 (226)

M. P.:
 $d. 800^\circ\text{C}$ (79)

Characteristics
Solid - gray white
crystal powder (226)

n_D^{20}
1.470 (79)

Toxicity

High (195)

Synthesis

Pass hydrogen into molten sodium dispersed in oil or mixed with a catalyst such as anthracene (above 250°C) (132).

Unique conditions, reaction products

NaH more reactive with H_2O than Na is (226); violent reaction with lower alcohols (132).

Solubility

s. molten NaOH ; i. liquid NH_3 (132)

Thermodynamic properties

	<u>gas</u>	<u>crystalline</u>	
standard heat of formation	29.88 kcal/mol	-13.60 ± .24 kcal/mol (at 101°C)	} (31)
standard free energy of formation	27.78 kcal/mol	-9.0 kcal/mol (at 90°C)	
entropy	44.93 cal/°mol	7.1 cal/°mol (at 102°C)	

Military and industrial uses

Powerful reducing agent (132).

Flammability

Finely powdered, spontaneously flammable in moist air (226).

SODIUM PHOSPHAMIDE

Mol. Wt.:

99.94

Formula:

NaPH₂

Synthesis

Pass hydrogen phosphide into solution of sodammonium in liquified ammonia, the gas is absorbed and hydrogen is evolved (quantity of H₂O generated corresponds to the formation of NaPH₂). A liquid is formed which does not mix with the ammonia although it is not quite insoluble in it, the liquid solidifies when slowly cooled (131).

Flammability

Spontaneously flammable (200).

HAFNIUM BOROHYDRIDE

Mol. Wt.:

197.32

Formula:

HF(BH₄)₄

M.P.:

29.0°C (71)

Characteristics

Solid - volatile (71)

B.P.:

118°C (extrapolated) (71)

Unique conditions, reaction products

Similar to aluminum borohydride, most volatile of known hafnium compounds (71).

Flammability

Like the borohydrides of Al, Be, Zr, hafnium borohydride inflames violently when exposed to air (71).

POTASSIUM HYDRIDE

Mol. Wt.:

40.11

Formula:

KH

M.P.:

Decomposes (79)

Characteristics

Solid - white needles (79)

$\frac{n_D}{d}$
1.453 (79)

d./sp. gr.:

1.47 (79)

Synthesis

$K + H_2 \xrightarrow[400^\circ C]{Pt/K}$ electrodes in H_2 stream, pass electric arc through electrodes) (89)

Unique conditions, reaction products

Reacts with steam or water, or acids to produce H_2 , vigorously reacts with oxidizing materials (195).

Solubility

d. hot and cold H_2O ; i. CS_2 , ether, benzene (79).

Thermodynamic properties

	gas	crystalline
heat of formations	30.0 kcal/mol	15.15 ± .16 kcal/mol
free energy of formations	25.1 kcal/mol	(30°C) -8.9 kcal/mol (21)
entropy	47.3 cal/°mol	(102 mm) 10.2 cal/°mol

Flammability

Ignites at lower temperature than NaH (39), spontaneously flammable (30).

LITHIUM ALUMINUM DEUTERIDE

d./sp. gr.: 1
1.029/cm³ (195)

Formulas
 $LiAlD_4$

B.P.:
d. 124°C (195)

Unique conditions, reaction products

React aluminum chloride with lithium deuteride (190).

Flammability

Spontaneously flammable in air (195).

LITHIUM ALUMINUM HYDRIDE

Mol. Wt.:
37.95

Formulas
 $LiAlH_4$

M.P.:
d. 125°C (79)

Characteristics:
Solid - white crystalline
powder (79)

d./sp. gr.: 1
.917 (79)

Toxicity

Highly caustic on inhalation, ingestion and on skin contact (142).

Synthesis

- (1) $4LiH + AlCl_3 \rightarrow LiAlH_4 + 3LiCl$ (80)
- (2) $4LiH + AlBr_3 \rightarrow LiAlH_4 + 3LiBr$ (80)

Unique conditions, reaction products

With water and acids yields hydrogen and heat enough to cause ignition (142).

Handling

Ship in air tight metal container, glass bottle or polyethylene bags in metal containers, steel or fiber drums; protect from physical damage, store in cool dry area (142).

Thermodynamic properties

heat of formation -24.68 kcal/mol

heat of formation (at 25°C) -165.87 kcal/mol (45)

Military and industrial uses

Powerful reducing agent for organic compounds (38).

Flammability

Spontaneously flammable in H₂O (68).

LITHIUM ALUMINUM TRI-TERT-BUTOXYHYDRIDE

Mol. Wt.:

254.04

Formula:

LiAl[OC(CH₃)₃]₃H

Synonyms

LATB

lithium tri-tert-

butoxyaluminumhydride

M.P.:

d. > 400°C (190)

Characteristics

Solid - white powder (190)

d./sp. gr.:

1.03 (190)

Solubility

s. dimethyl ether of diethylene glycol, tetrahydrofuran, diethyl ether (190)

Military and industrial uses

Stereospecific reductions of steroid ketones; reduction of acid chlorides to aldehydes (190).

Flammability

"Reacts with H₂O to evolve H₂, usually does not ignite" (190).

LITHIUM BOROHYDRIDE

Mol. Wt.:

21.78

Formula:

LiBH₄

M.P.:

d. 279°C (79)

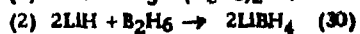
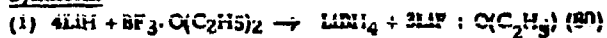
Characteristics

Solid - rhombic crystals,
white cubic crys. (79)

d./sp. gr.:

.66 (79)

Synthesis



Solubility

v. sl. s. cold H_2O (79)

Thermodynamic properties

heat of combustion: 136.000 cal/g mol (107)

enthalpy (at 25°C): -74.51 kcal/mol (45)

heat of formation (at 25°C): -72.14 kcal/mol (45)

heat of formation (at 298.16°C): -44.15 kcal/mol (45)

Military and industrial uses

Source of hydrogen and of other borohydrides, reducing agent for aldehydes, ketones and esters (190).

Flammability

May ignite on contact with H_2O or in moist air (69).

LITHIUM HYDRIDE

Mol. Wt.:

7.95

Formulas

LiH

M.P.:

680°C (79)

Characteristics

Solid - white crystals (79)

d./sp. gr.:

.82 (79)

B.P.:

d. 850°C (133)

Toxicity

Tolerance level - .025 mg/m³ (195).

Synthesis



Unique conditions, reaction products

Reacts with alcohol, carboxylic acids, chlorine and ammonia at 400°C to liberate hydrogen (132).

Solubility

d. cold H_2O ; v. sl. s. acid (79)

Handling

Immerse in mineral oil or paraffin wax (160).

Thermodynamic properties

high frequency dielectric constant: 3.61 (159)

lattice constant: 4.0835 Å (159)

lattice energy (Born-Haber cycle): 218.8 kcal/mol (159)

	<u>gas</u>	<u>crystalline</u>	
entropy (at 25°C)	40.77 cal/mol	5 cal/mol	} (30)
free energy of formation (at 25°C)	25.2 kcal/mol	-16.72 kcal/mol	
heat of formation (at 25°C)	30.7 kcal/mol	-21.34 ± .15 kcal/mol	

Military and industrial uses

Used as a desiccant, source of H₂, condensing agent with ketones and acid esters (132).

Flammability

Can ignite spontaneously in moist air (195).

MAGNESIUM HYDRIDE

Mol. Wt.:

26.33

Formula:

MgH₂

M.P.:

d. 280°C (79)

Characteristics

Solid - white tetragonal
crystal or mass (79)

d./sp. gr.:

1.419 (79)

Synthesis

$Mg + H_2 \rightarrow MgH_2$ (80)

Unique conditions, reaction products

Violent reaction with H₂O ($MgH_2 + 2H_2O \rightarrow Mg(OH)_2 + H_2$) (132).

Solubility

Violent d. cold H₂O; i. ether (79).

Thermodynamic properties

heat of formation (at 298°C) -21.71 ± .65 kcal/mol (161).

Flammability

Ignites spontaneously with air to yield MgO + H₂O; also ignites with tap water but not in distilled H₂O (132).

MANGANESE (II) ALUMINOHYDRIDE

Mol. Wt.:

116.90

Formula:

Mn(AlH₄)₂

M.P.:

d. -80°C (13)

Synthesis

Form solid complex with LiBr, heat complex with LiAlH₄ near freezing point of ether, yields a precipitate of aluminohydride (13).

Flammability:

Spontaneously flammable (13)

TRISILICYLAMINE

Mol. Wt.:

107.34

Formula:

$(\text{SiH}_3)_3\text{N}$

Synonyms:

Nitrilo - Tri - silane

Trisilylamine

Nitrosilane

M.P.:

-105.6°C (226)

Characteristics:

Liquid - colorless (226)

d./sp. gr.:

.895-106 (226)

B.P.:

52°C (226)

Unique conditions, reaction products:

Reacts with H_2O or steam to produce flammable vapors (94).

Solubility:

s. organic solvent (226)

Flammability:

Spontaneously flammable (226).

SODIUM ALUMINUM HYDRIDE

Mol. Wt.:

54.00

Formula:

NaAlH_4

M.P.:

d. 183°C (190)

d. 230°C (133)

d./sp. gr.:

1.24 g/cc (190)

Synthesis:

React AlCl_3 with NaH (190)

Thermodynamic properties:

heat of formation (at 25°C): 13.5 kcal/mol (190)

free energy of formation (at 25°C): 3.0 kcal/mol (190)

Military and industrial uses:

Used to reduce carbonyl and carboxyl groups to hydroxyl groups, to reduce amides to amines and to reduce organic halides to hydrocarbons (133).

Flammability:

Fire and possible explosion if water, as liquid or vapor comes in contact with (133).

DIPHOSPHINE

Mol. Wt.:
65.98

Formulas
 PH_2 or P_2H_4

M.P.:
-99°C (226)

Characteristics
Liquid - colorless (79)

d./sp. gr.:
1.012 (79)

B.P.:
51.7°C (226)

Synthesis

- (1) $\text{Ca}_3\text{P}_2 + 6\text{H}_2\text{O} \rightarrow 3\text{Ca}(\text{OH})_2 + \text{P}_2\text{H}_4 + \text{H}_2$ (131)
 (2) Acetyl chloride reacts with $4\text{H}_3\text{PO}_2 \rightarrow \text{H}_3\text{PO}_4 + \text{H}_3\text{PO}_3 + \text{H}_2 + \text{P}_2\text{H}_4$ (131)

Solubility:

1. hot and cold H_2O ; s. alcohol, turpentine (79)

Thermodynamic properties

heat of vaporization: 6.89 kcal (231)
 trouton's constant: 21 (231)

Flammability:

Spontaneously flammable in air (143).

PHOSPHINE

Mol. Wt.:
34.00

Formulas
 PH_3

Synonyms
Hydrogenphosphide
Phosphoretted hydrogen
Phosphorus trihydride

M.P.:
-133.5°C (226)

Characteristics
Gas - colorless (226)

d./sp. gr.:
1.3171 (226)
1.5290 (226)

B.P.:
-87.4°C (226)

Toxicity:

Moderate; high on inhalation, moderate as irritant; tolerance .05 ppm (.07 mg/m³ air); central nervous system depressant; irritates lungs, dilates heart, can cause hyperemia of visceral organs (195).

Synthesis

- (1) $4\text{P} + 3\text{KOH} + 3\text{H}_2\text{O} \rightarrow \text{PH}_3 + 3\text{KH}_2\text{PO}_2$ (80); (2) $\text{Ca}_3\text{P}_2 + 6\text{H}_2\text{O} \rightarrow 2\text{PH}_3 + 3\text{Ca}(\text{OH})_2$ (80);
 (3) $\text{PH}_4\text{I} + \text{KOH} \rightarrow \text{PH}_3 + \text{KI} + \text{H}_2\text{O}$ (80)

Unique conditions, reaction products

Emits highly toxic phosphorus fumes when heated to decomposition (195); reacts with concentrated HNO_3 with violent decomposition and flames; spontaneous ignition in presence of nitrous acid (143).

Ignition temperatures

Autoignition temperature: 40°-65°C (97).

Solubility:

d. s. H_2O ; s. alcohol, ether (226)

Thermodynamic properties

heat of formation 2.3 kcal/mol (226)

entropy (at 25°C): 50.23 cal/*mol (226)

enthalpy -1.6 ± .4 (78)

Flammability:

Spontaneously flammable (226)

TRISILYL PHOSPHINE

Mol. Wt.:

124.32

Formula:

$P(SiH_3)_3$

Characteristics

Liquid - colorless (226)

V.P.:

83 mm (at 0°C) (226)

Solubility:

d. H_2O ; s. organic solvent (226).

Flammability:

Spontaneously flammable (226).

PLUTONIUM HYDRIDE

Mol. Wt.:

244.02

Formula:

PuH_2

d./sp. gr.:

10.4 (103)

Characteristics

Solid - cubic (103)

Thermodynamic properties

heat of formation (at 79°C): -37.0 kcal/mol (23)

Flammability:

Spontaneously flammable (137).

RUBIDIUM HYDRIDE

Mol. Wt.:

86.48

Formula:

RbH

M.P.:

d. 300°C (79)

Characteristics

Solid - colorless needles (79)

d./sp. gr.:

2.60 (79)

Synthesis

$Rb + I_2 \xrightarrow[\text{(high temperature)}]{620-680^\circ C} RbI$ (89)

Unique conditions, reaction products

Violent reaction with H_2O (89)

Solubility:

i. organic solvents (89); d. cold and hot H_2O , acid (79)

Thermodynamic properties

	<u>gas</u>	<u>crystalline</u>
heat of formation	33.0 kcal/mol	-11.3 kcal/mol (at $102^\circ C$) (31)

Military and industrial uses

Used as light sensitive element for photocells (89).

Flammability:

Ignites on contact with air due to exothermic reaction of hydride with moisture (89).

SILICON HYDRIDES

Mol. Wt.:

$(30.10)_x$

Formula:

$(SiH_2)_x$

Synonyms:

Polysilanes

Toxicity:

High (acute local) as irritant, on ingestion and on inhalation (195).

Synthesis

$CaSi + 2HCl \rightarrow (SiH_2)_x + CaCl_2$ (80).

Unique conditions, reaction products

Reacts with alkali hydroxides to yield hydrogen (80).

Flammability:

Spontaneously flammable in air leaving SiO_2 residue (80).

SILANE

Mol. Wt.:

32.12

Formula:

SiH_4

Synonyms:

Silicon tetrahydride
Silicon hydride
Silicane

M.P.:

$-185^\circ C$ (226)

Characteristics

Gas - colorless (226)

d./sp. gr.:

(liq) .34 -185 (226)

(gas) 1.44 (193)

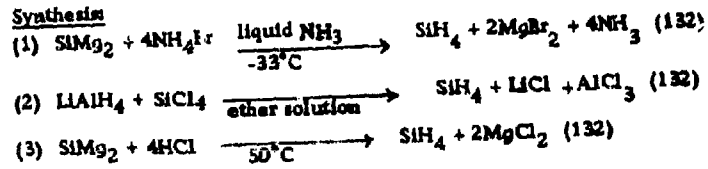
B.P.:

$-111.8^\circ C$ (226)

Toxicity

High (acute local) as irritant, on ingestion or on inhalation (190).

Synthesis



Solubility

d. air, alkaline solvent; v. organic solvent (226)

Thermodynamic properties

heat of formation 11.9 kcal./mol (226)

Flammability

Spontaneously flammable (226)

SILYL PHOSPHINE

Mol. Wt.:

64.11

Formula:

H_3SiPH_2

Synonyms

Phosphinyl Silane

M.P.:

< -185°C (99)

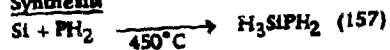
Characteristics

Liquid (79)

B.P.:

12.7°C (extrapolated) (53)

Synthesis



Solubility

d. alkaline solvents (79)

Flammability

Thermally stable to 400°C but ignites if traces of O_2 are present (157)

OXADISILANE

Mol. Wt.:

76.18

Formula:

H_3SiSiHO

Flammability

Spontaneously flammable in air (143).

DISILANE

<u>Mol. Wt.:</u> 62.23	<u>Formula:</u> Si_2H_6	<u>Synonyms:</u> Silicoethane
<u>M.P.:</u> -132.5°C (226)	<u>Characteristics:</u> Gas - colorless (226)	
<u>d./sp. gr.:</u> .686-25 (226)	<u>B.P.:</u> -15°C (226)	

Unique conditions, reaction products

Explodes with SF_6 ; reacts violently with CCl_4 and chloroform (136).

Solubility:

s. organic solvent; d. alkaline solvent (226)

Thermodynamic properties

enthalpy -18.3 ± .3 kcal/mol (78)
heat of formation 17.4 ± 0.3 kcal/mol (78); -35.8 kcal/mol (59)
heat of combustion -575.3 kcal/mol (at 293°K) (60)
enthalpy of formation -36.2 kcal/mol (at 293°K) (60)

Flammability:

Spontaneously flammable (226).

TRISILANE

<u>Mol. Wt.:</u> 92.33	<u>Formula:</u> Si_3H_8	<u>Synonyms:</u> Trisilicon octahydride Trisilane propane Silicon hydride
<u>M.P.:</u> -117.4°C (226)	<u>Characteristics:</u> Liquid - colorless (226)	
<u>d./sp. gr.:</u> .743 ⁰ (226) .725 ²⁵ (226)	<u>B.P.:</u> 53°C (226)	<u>V.P.:</u> 95.5 ⁰ (195)

Solubility:

s. organic solvent; d. H_2O , CCl_4 (226)

Thermodynamic properties

enthalpy of formation -54.4 kcal/mol (60)
heat of formation -54.1 kcal/mol (59)
heat of combustion (at 293°K) -835.1 ± 7 kcal/mol (60)

Flammability:

Spontaneously flammable (226).

SILOXANE

Mol. Wt.:
222.56

Formula:
 $\text{Si}_6\text{O}_3\text{H}_6$

Synonyms:
Hexaoxocyclosilane

M.P.:
d. 140°C (79)

Characteristics:
Solid - white platelets (79)

d./sp. gr.:
1.32²⁰ (79)

Solubility:
sl. d. cold H_2O ; slight d. hot H_2O (79); d. air (79)

Flammability:
Spontaneously flammable (50)

STRONTIUM HYDRIDE

Mol. Wt.:
89.64

Formula:
 SrH_2

M.P.:
d. 675°C (79)

Characteristics:
Solid - white crystalline (226)

d./sp. gr.:
3.72 (226)

B.P.:
Sublimes 1000°C (in H_2) (79)

Synthesis:
 $\text{Sr} + \text{H}_2 \rightarrow \text{SrH}_2$ (80)

Unique conditions, reaction products:
Vigorous reaction with H_2O (226)

Solubility:
d. hot and cold H_2O , alcohol (79)

Thermodynamic properties:
heat of formation: 42.2 kcal/mol (226)
free energy of formation (at 90°C): -33.1 kcal/mol (32)
entropy (at 209°C): 13 cal/mol (32)

THORIUM HYDRIDE

Mol. Wt.:
235.07

Formula:
 ThH_3

Characteristics:
Solid - black powder (226)

Flammability:

Spontaneously flammable in air (26).

THORIUM HYDRIDE

Mol. Wt.:

943.00

Formula:

Th₄H₁₅

Flammability:

Spontaneously flammable in air (51).

URANIUM BOROHYDRIDE

Mol. Wt.:

282.53

Formula:

U(BH₄)₃

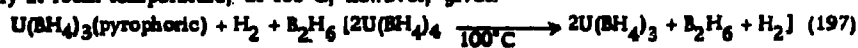
Characteristics:

Solid - brown

non volatile (197)

Toxicity:

Treat UF₄ with Al(BH₄)₃ at room temperature. The dark green volatile crystals of U(BH₄)₄ decompose very slowly at room temperature, at 100°C, however, gives



Flammability:

Spontaneously flammable and likely to detonate in air (197).

URANIUM HYDRIDE

Mol. Wt.:

241.05

Formula:

UH₂

d./sp. gr.:

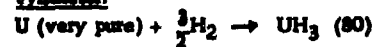
11.4 (79)

Characteristics:

Solid - black powder

cubic (79)

Synthesis:



Unique conditions, reaction products:

Powerful reducing agent; vigorous reaction with H₂O (2U₃ + 4H₂O → 2UO₂ + 7H₂) (80).

Flammability:

Spontaneously flammable (80).

ZIRCONIUM BOROHYDRIDE

Mol. Wt.:

150.50

Formula:

$Zr(BH_4)_4$

M.P.:

28.7°C (71)

Characteristics

Volatile (71)

B.P.:

123°C (71)

Flammability:

Spontaneously flammable in air (71).

ALUMINUM AMINOBOROHYDRIDES

Characteristics

Liquid - oily (72)

Synthesis

Aluminum borohydride reacts with $(CH_3)_2NBH_2 \rightarrow (CH_3)_2NB_2H_5$ and aminoborohydrides of aluminum (30).

Unique conditions, reaction products

Violently attacked by air or moisture (30); reacts with diborane to yield $(CH_3)_2NB_2 + Al(BH_4)_3$ (30).

Flammability:

"Oily liquid aluminum borohydrides are spontaneously inflammable ..." (72).

(h) NITRIDES

TRIAZIDO BORINE

Mol. Wt.:
136.82

Formulas
 $B(N_3)_3$

Unique conditions, reaction products:

Explodes above -45°C or when added to H_2O (156).

BARIUM AZIDE

Formulas
 BaN_6

Unique conditions, reaction products:

Heat in vacuum to $140-160^\circ\text{C} \rightarrow$ pyrophoric residue (227).

Flammability:

Spontaneously flammable (227)

CALCIUM NITRIDE

Mol. Wt.:
148.25

Formulas
 Ca_3N_2

M.P.:
 1195°C (79)
 900°C (195)

Characteristics
Solid - brown hexagonal
crystal (79)

d./sp. gr.:
2.6557 (79)

Synthesis

$3Ca + N_2 \rightarrow Ca_3N_2$ (80)

Solubility:

Evolves ammonia with moisture (195); s. dilute acid; d. absolute alcohol (79).

Thermodynamic properties

standard heat of formations	<u>crystal</u> -103.2 kcal/mol	} (79)
free energy of formation (at 25°C);	-88.1 kcal/mol	
entropy (at 25°C);	25 cal/ $^\circ\text{mol}$	

Flammability:

Spontaneously flammable in air (143).

CADMIUM NITRIDE

Mol. Wt.:
365.23

Formula:
 Cd_3N_2

d./sp. gr.:
7.67 (131)

Synthesis:
 $\text{Cd}(\text{NH}_2)_2 \xrightarrow[180^\circ\text{C}]{\Delta \text{ vacuo}} \text{Cd}_3\text{N}_2 + \text{NH}_3 \quad (162).$

Unique conditions, reaction products

Violent explosion with H_2O (143); explodes on reaction with dilute acids and bases (131).

Thermodynamic properties

standard heat of formation (at 25°C):

crystalline
38.6 kcal/mo. (79)

CERIUM NITRIDE

Mol. Wt.:
154.12

Formula:
 CeN

Synthesis:
Heat cerium in nitrogen (131).

Unique conditions, reaction products

With a few drops of water exothermic reaction is sufficient to ignite hydrogen and ammonia given off (142).

Thermodynamic properties

heat of formations -78 kcal/mol (131)

entropy (at 298°K): -25.0 e. u. (131)

free energy of formation (at 298°K): -70.550 kcal/mol (131)

Flammability:

Spontaneous incandescent oxidation with moist air (143).

COBALT NITRIDE

Mol. Wt.:
72.94

Formula:
 CoN

Characteristics

Solid - black powder (80)

Synthesis

$\text{Co}(\text{HN}_2)_3 \rightarrow \text{CoN} + 2\text{NH}_3$ (80); cobalt amide in vapor pressure eudiometer, decompose at $50^\circ - 70^\circ\text{C}$ in the absence of air (absorb evolved NH_3 on concentrated H_2SO_4) all NH_3 is eliminated yielding CoN (80).

Flammability:

Spontaneously flammable (80).

POTASSIUM NITRIDE

Mol. Wt.:

131.31

Formula:

K_2N

M. P.:

Decomposes (79)

Characteristics

Solid - greenish black (79)

Solubility:

d. cold H_2O (79)

Flammability:

Generally spontaneously flammable in air (143).

DISULPHUR DINITRIDE

Mol. Wt.:

92.12

Formula:

S_2N_2

Characteristics

Solid - volatile colorless crystal (80)

Synthesis

$\text{S}_4\text{N}_4 \xrightarrow[\text{irradiation}]{\text{thermal}} 2\text{S}_2\text{N}_2$ (80)

Unique conditions, reaction products

Explodes above 30°C in air (80).

Solubility

s. benzene, ether, CCl_4 , acetone (80)

STRONTIUM AZIDE

Mol. Wt.:

171.63

Formula:

SrN_6

Unique conditions, reaction products

Heat in vacuum to $140^\circ - 160^\circ\text{C} \rightarrow$ pyrophoric residue (227)

Flammability:

Spontaneously flammable (227)

THORIUM NITRIDE

Mol. Wt.:

752.14

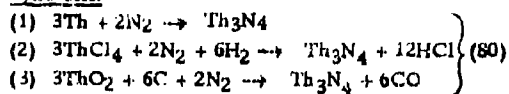
Formula:

Th_3N_4

Characteristics:

Solid - dark brown powder
or black crystal (79)

Synthesis:



Unique conditions, reaction products:

Burns in air with incandescence (143).

Solubility:

sl. d. cold H_2O ; d. hot H_2O ; s. HCl (79)

AZIDO THALLIUM

Mol. Wt.:

246.39

Formula:

TlN_3

Synonyms:

Thallium azide

M. P.:

330°vac (79)

Characteristics:

Solid - explosive tetragonal
(79)

Unique conditions, reaction products:

Explodes in air (103).

Solubility:

i. alcohol, ether (79)

URANIUM NITRIDE

Mol. Wt.:

252.04

Formula:

UN

M. P.:

(about) $2630 \pm 50^\circ\text{C}$ (79)

Characteristics:

Solid - brown powder (79)

d./sp. gr.:

14.31 (79)

Synthesis

(1) Thermal decomposition of higher nitrides of uranium in a vacuum; (2) by strongly heating mixtures of uranium and the higher nitrides; (3) reduction of higher nitrides with hydrogen; (4) direct reaction of ammonia or nitrogen with uranium hydride; or (5) direct reaction between nitrogen and uranium (131).

Thermodynamic properties

standard heat of formation	<u>crystalline</u>	}
standard free energy of formation	-80 kcal/mol	
entropy (at 25°C)	-75 kcal/mol	
	18 cal/mol	(79)

Flammability

Spontaneously flammable (240).

(1) OXIDES

BARIUM PEROXIDE

Mol. Wt.:
169.34

Formula:
 BaO_2

Synonyms:
Barium bioxide
Barium dioxide

M. P.:
450°C (79)

Characteristics:
Solid - gray white
powder (79)

d./sp. gr.:
4.96 (79)

B.P.:
200°C (in O_2) (79)

Toxicity:

Slight as irritant on ingestion and on inhalation (195); threshold limiting value .5 mg/m³ (142).

Synthesis

$\text{BaO} \xrightarrow{\text{O}_2} \text{BaO}_2$ (190)

Unique conditions, reaction products:

Reacts with large quantities H_2O explosively (144).

Solubility:

v. sl. s. cold H_2O ; d. hot H_2O ; s. dilute acids; i. acetone (79)

Handling:

Protect from physical damage, keep from combustible organic or other readily oxidized materials, keep from moisture (142).

Thermodynamic properties

standard heat of formation -150.5 kcal/mol (79)

transition temperatures 723°K (142).

heat of transition 5.7 kcal/mol (142).

Military and industrial uses

Used to manufacture oxygen and hydrogen peroxide, bleaching, tracer bullets, primer in combination with aluminum powder in aluminic thermic welding, oxygenated water (190).

CHROMOUS MONOXIDE

Mol. Wt.:
68.00 (79)

Formula:
 CrO

Characteristics

Solid - black powder (79)

Solubility:

1. cold and hot H_2O , dilute HNO_3 (79)

Flammability:

Spontaneously flammable (59).

CESIUM OXIDE

Mol. Wt.:

281.81

Formula:

Cs_2O

M.P.:

d. $400^\circ C$ (79)

$420^\circ C$ in N_2 (79)

Characteristics:

Solid - orange needles (79)

d./sp. gr.:

4.25 (79)

Synthesis:

$2Cs + 1/2O_2 \rightarrow Cs_2O$ (80)

Solubility:

v. s. cold H_2O ; d. hot H_2O ; s. acid (79)

Thermodynamic properties:

crystalline

standard heat of formation:

-75.9 kcal/mol (79)

entropy:

23 e.u. (79)

Flammability:

Spontaneously flammable in H_2O (vigorous) (80).

FEROUS OXIDE

Mol. Wt.:

71.85

Formula:

FeO

Synonyms:

iron oxide

M.P.:

$1420^\circ C$ (79)

Characteristics:

Solid - black cubic (79)

d./sp. gr.:

5.7 (79)

n_D

2.32 (79)

Synthesis:

(1) Thermal decomposition of iron formate or iron oxalate results in carbon bearing FeO

($FeC_2O_4 \rightarrow FeO + CO + CO_2$) (116); (2) decompose FeC_2O_4 in quartz vessel, lower section ($850^\circ C$) remove nascent gases as quickly as possible, FeC_2O_4 trapped in heated portion when FeO is formed (all gas is removed) chill quickly (to prevent decomposition) (80); (3) heat Fe_2O_3 and reduced iron in sealed preevacuated quartz tubes 3 days at $900^\circ C$ (80).

Thermodynamic properties

temperature of transitions 1641°K
heat of transitions 7.5 kcal/mol
entropy (at 298°K): 12.9 e. u.

(79)

Flammability:

Oxide is spontaneously flammable, burns to Fe_2O_3 on exposure to air but retains spinel structure (116).

INDIUM MONOXIDE

Mol. Wt.:

130.81 (79)

Formula:

In_2O_3

Characteristics

White gray (79)

Solubility:

i. cold H_2O ; s. alcohol (79)

Thermodynamic properties

standard heat of formations
temperature of transitions
heat of transition;
entropy (at 298°K):

gas

91 kcal/mol
600°K
4.5 kcal/mol
14.5 e. u.

(79)

Flammability:

Spontaneously flammable (50).

POTASSIUM PEROXIDE

Mol. Wt.:

110.20

Formula:

K_2O_2

M.P.:

490°C (79)

Characteristics

Solid - white, amorphous
deliquescent (79)

B.P.:

Decomposed (79)

Synthesis

Oxidation of potassium in oxygen (190).

Thermodynamic properties

standard heat of formations
temperature of transitions
heat of transitions
entropy (at 298°K):

crystalline

-118 kcal/mol
980°K
6.8 kcal/mol
23 e. u.

(79)

Flammability:

Ignites or explodes with H_2O (218).

MANGANESE HEPTOXIDE

Mol. Wt.:

221.87

Formulas

Mn_2O_7

M.P.:

5.9°C (79)

Characteristics

Liquid - dark red oil (79)

d./sp. gr.:

2.396²⁰ (79)

B.P.:

d. 55°C (explodes 95°C) (79)

Unique conditions, reaction products

Forms in $KMnO_4$ - H_2SO_4 mixtures (166); reacts with H_2O exothermically - initiates explosion (166).

Solubility:

v. s. cold H_2O ; d. hot H_2O ; s. H_2SO_4 (79)

Flammability:

Explodes 70°C (166).

MOLYBDENUM DIOXIDE

Mol. Wt.:

127.94

Formulas

MoO_2

d./sp. gr.:

6.47 (79)

Characteristics

Solid - lead gray, tetragonal
or monoclinic (79)

Synthesis

$MoO_3 + H_2 \xrightarrow{300^\circ C} MoO_2$ (240)

Solubility:

i. cold and hot H_2O ; sl. s. hot concentrated H_2SO_4 ; i. alkaline solvent, HCl, HF (79)

Thermodynamic properties

heat of formation (at 25°C):

temperature of transition:

heat of transition:

entropy (at 298°K):

crystalline

-130 kcal/mol

2200°K

16 kcal/mol

14.5 e.u.

} (79)

Flammability:

Spontaneously flammable (240).

MOLYBDENUM TRIOXIDE

Mol. Wt.:
143.94

Formulas
 MoO_3

Synonyms
Molybdic anhydride
Natural molybdate

M.P.:
795°C (79)

Characteristics
Solid - colorless, or white
yellow rhombic

d./sp. gr.:
4.6922¹ (79)

B.P.:
(sublimes) 1155760 (79)

Synthesis

(1) roasting of molybdenite (190); (2) by ignition of the metal sulfides, lower oxides and of molybdic acids (190)

Solubility:

sl. s. H_2O ; s. HNO_3 and concentrated HCl solution (190); s. acids, alkaline sulfides, NH_4OH (79)

Thermodynamic properties

	<u>crystalline</u>	<u>aqueous solution</u>
standard heat of formations	-180.33 kcal/mol	-188.1 kcal/mol
free energy of formation (at 25°C)	-161.95 kcal/mol	
entropy (at 25°C)	18.68 cal/°mol	
temperature of transitions	1068°K	
heat of transitions	12.54 kcal/mol	

(79)

Flammability:

Spontaneously flammable (238)

PHOSPHORUS TRIOXIDE

Mol. Wt.:
109.95

Formulas
 P_2O_3

Synonyms
Diphosphorus trioxide

M.P.:
23.8°C (79)

Characteristics
Solid - colorless or white
powder or monoclinic
deliquescent (79)

V.F.:
10-53.0 (195)

d./sp. gr.:
2.1352¹ (79)

B.P.:
173.8°C (N_2 atmosphere) (79)

Synthesis

Precipitated by treating PCl_3 with tetramethyl ammonium sulfite in liquid SO_2
 $2\text{PCl}_3 + 3[(\text{CH}_3)_4\text{N}]_2\text{SO}_3 \rightarrow \text{P}_2\text{O}_3 + 3\text{SO}_2 + 6[(\text{CH}_3)_4\text{N}]\text{Cl}$ (132)

Solubility:

d. hot H_2O , cold H_2O to H_3PO_3 ; s. C_6H_6 , CS_2 , ether, chloroform (79)

Flammability:

Melted P_2O_3 readily ignites in air; when thrown into O_2 at 50-60°C ignites with brilliant flame (143).

SULFUR TRIOXIDE

Mol. Wt.:
80.06

Formulas
 SO_3

Synonyms:
Sulfuric acid anhydride

M.P.:
 α 62.3°C
 β 32.5°C (79)
 γ 16.8°C

Unique conditions, reaction products:

Reacts with moisture in air to form white fog (23).

Thermodynamic properties:

	<u>gas</u>	<u>liquid</u>	
standard heat of formations	-94.45 kcal/mol	-104.67 kcal/mol	} (79)
free energy of formation (at 25°C)	-38.52 kcal/mol		
entropy (at 25°C)	61.24 cal/°mol		

Military and industrial uses:

German army used SO_3 for smoke screens in World War I (23).

TRISULPHUR DINITROGEN DIOXIDE

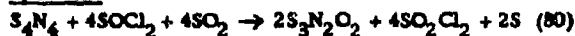
Mol. Wt.:
156.18

Formulas
 $\text{S}_3\text{N}_2\text{O}_2$

M.P.:
100.7°C (without d.)

Characteristics
Solid - pale yellow crystals (80)

Synthesis:



Unique conditions, reaction products:

Turns red at 80°C, with further heating yields spontaneously flammable (300°C) yellow vapor (80).

SILICON MONOXIDE

Mol. Wt.:
44.09

Formulas
 SiO

M.P.:
> 1702°C (79)

Characteristics
Solid - white cubic (79)

d./sp. gr.:
2.13 (79)

B.P.:
1880°C (79)

Synthesis:

High vacuum sublimation of silicon and quartz mixture (132).

Solubility

1. hot and cold H_2O ; s. dilute HF and HNO_3 (79)

Thermodynamic properties

temperature of transitions 2550°K
heat of transitions 12 kcal/mol
entropy (at 298°K) 6.5 e.u. } (79)

Flammability

Spontaneously flammable (50).

TITANIUM MONOXIDE

Mol. Wt.:

63.90

Formula:

TiO

M.P.:

1750°C (79)

Characteristics

Solid - yellow black prism (79)

d./sp. gr.:

4.93 (79)

B.P.:

> 3000°C (79)

Synthesis

$Ti + TiO_2 \rightarrow 2TiO$ (80)

Solubility

s. dilute H_2SO_4 ; 1. HNO_3 (79); s. dilute HCl [$Ti^{++} + H^+ \rightarrow Ti^{+++} + \frac{1}{2}H_2$] (80)

Thermodynamic properties

standard heat of formation (at 25°C) 43 kcal/mol
solid transition temperatures α 1264°K; β d. 2010°K } (79)
heat of transitions α .82 kcal/mol
entropy (at 298°K) α 2.31 e.u.

Flammability

Spontaneously flammable (50).

URANIUM OXIDE

Mol. Wt.:

270.03

Formula:

UO_2

Synonyms

Uranous oxide

Uranium dioxide

M.P.:

2500°C (79)

2176°C (under N_2) (80)

Characteristics

Solid - brown, black rhombic
or cubic (79)

d./sp. gr.:

10.96 (79)

Synthesis

$\text{UO}_2\text{C}_2\text{O}_4 \cdot 3\text{H}_2\text{O} \rightarrow \text{UO}_2 + 2\text{CO}_2 + 3\text{H}_2\text{O}$ (preparation of hot concentrated solution of uranyl nitrate with oxalic acids yields a yellow powder of $\text{UO}_2\text{C}_2\text{O}_4 \cdot 3\text{H}_2\text{O}$ in a stream of hydrogen even below red heat yields a black very fine pyrophoric UO_2 powder) (80).

Solubility

sl. cold and hot H_2O ; s. HNO_3 , concentrated H_2SO_4 (79)

Thermodynamic properties

standard heat of formation	<u>crystalline</u> -270 kcal/mol	} (79)
free energy of formation (at 25°C)	-257 kcal/mol	
temperature of transition	3000°K	
entropy (at 298°K)	18.63 e. u.	

Military and industrial uses

Used as fissionable dust carried in a gas for use in an ADFR (Armour Dust Fissionable Reactor). The gas is CO_2 , beryllium oxide the moderator, and aluminum oxide the lining material (112).

Flammability

Spontaneously flammable black powder (80).

URANEUM HYDRIDE

Mol. Wt.:

273.07

Formulas

$\text{UH}(\text{OH})_2$

Synthesis

Metal uranium dissolves in excess $\text{HCl}(\text{6N})$, drying the precipitate in a vacuum yields $\text{UH}(\text{OH})_2$ (102)

Unique conditions, reaction products

With aqueous KMnO_4 yields hydrogen, with heat yields $\text{U}_3\text{O}_8 + \text{H}_2$ (102)

Flammability

Spontaneously flammable (240).

VANADIUM SESQUIOXIDE

Mol. Wt.:

149.88

Formulas

V_2O_3

Synonyms

Vanadium trioxide

M.P.:

1970°C (79)

Characteristics

Solid - black crystal (79)

d./sp. gr.:

4.8718
4 (79)

Solubility

sl. s. cold H_2O ; s. hot H_2O , s. HNO_3 , HF, alkaline solvents (79)

Thermodynamic properties:

standard heat of formation: -290 kcal/mol
free energy of formation (at 25°C): -271 kcal/mol
temperature of transition (sol): 2240°K
entropy (at 25°C): 23.58 kcal/mol
heat of transition: 24 kcal/mol

} (79)

Flammability:

Spontaneously flammable (50)..

(J) PHOSPHIDES

ALUMINUM PHOSPHIDE

Mol. Wt.:
57.96

Formula:
AlP

M.P.:
> 1700°C (231)

Characteristics:
Solid - yellow gray to dark
crystals (132)

d./sp. gr.:
2.85¹⁵₄ (132)

Synthesis

$\text{Al} + \text{P} \rightarrow \text{AlP}$ grind aluminum powder and red phosphorus together, place in vycor reaction tube, flush with hydrogen, heat distillation flask in continuous hydrogen until the phosphorus condenses on the aluminum phosphide mixture, ignite in a small hot flame and drive out excess phosphorus (80).

Unique conditions, reaction products

Yields phosphine on reaction with H_2O (132)

CALCIUM PHOSPHIDE

Mol. Wt.:
182.19

Formula:
 Ca_3P_2

Synonyms:
Photophor

M.P.:
Ca 1600°C (79)

Characteristics:
Solid - gray lumps (79)

d./sp. gr.:
2.51 (79)

Synthesis

(1) $3\text{C} + 2\text{P} \rightarrow \text{CaP}_2$; (2) $3\text{Ca}_3(\text{PO}_4)_2 + 16\text{Al} \rightarrow 3\text{Ca}_3\text{P}_2 + 8\text{Al}_2\text{O}_3$ (cannot separate Ca_3P_2 and Al_2O_3) (80)

Solubility:

d. in cold H_2O ; s. acids; l. alcohol, ether, C_6H_6 (132)

Thermodynamic properties

heat of formation -120.5 kcal/mol (226)

Military and industrial uses

Used to prepare P_2H_4 (80); used in signal fires (132).

Flammability:

With water produces phosphine (PH_3) and diphosphine (PH_2); diphosphine ignites spontaneously in air (226).

CESIUM PHOSPHIDE

Mol. Wt.:
520.67

Formula:
 Cs_2P_5

Characteristics
Reddish brown (231)

Unique conditions, reaction products

Reacts with H_2O or moist air instantaneously to yield phosphine (231)

CUPRIC PHOSPHIDE

Mol. Wt.:
252.6

Formula:
 Cu_3P_2

M.P.:
Decomposes (195)

Characteristics
Solid - black powder (131)

d./sp. gr.:
6.67 (195)

Synthesis

Pass phosphine over heated cupric chloride or through solution of cupric sulphate (131).

Unique conditions, reaction products

Yields spontaneously flammable phosphine on contact with H_2O (195).

POTASSIUM PHOSPHIDE

Mol. Wt.:
233.05

Formula:
 K_2P_5

M.P.:
About 650°C (231)

Characteristics
Reddish brown (231)

Unique conditions, reaction products

Phosphine produced instantaneously on reaction with H_2O or moist air (231).

LITHIUM PHOSPHIDE

Mol. Wt.:
168.73

Formula:
 Li_2P_5

M.P.:
About 650°C (231)

Characteristics
Solid - reddish brown powder (231)

Unique conditions, reaction products

Phosphine produced from reaction of Li_2P_5 with H_2O or moist air (231).

MAGNESIUM PHOSPHIDE

Mol. Wt.:

134.88

Formulas

Mg_3P_2

d./sp. gr.:

2.055 (79)

Characteristics

Solid - yellow green cubic
crystals (79)

Toxicity:

Heat magnesium with dehydrated organic or inorganic substances containing phosphorus, heat mixture of magnesium filings and red (or yellow) phosphorus to redness in a glass vessel (131).

Unique conditions, reaction products

Mg_3P_2 produces phosphine and diphosphine on contact with H_2O (226).

Solubility:

d. hot and cold H_2O ; d. dilute mineral acid; sl. d. concentrated H_2SO_4 (79).

SODIUM PHOSPHIDE

Mol. Wt.:

200.83

Formulas

Na_2P_5

M.P.:

About 650°C (231)

Characteristics

Solid - reddish brown
powder (231)

Unique conditions, reaction products

Reacts instantaneously with H_2O or moist air to yield phosphine (231).

RUBIDIUM PHOSPHIDE

Mol. Wt.:

325.81

Formulas

Rb_2P_5

Characteristics

Reddish brown (231)

Unique conditions, reaction products

Reacts instantaneously with H_2O or moist air to yield phosphine (231).

STANNIC PHOSPHIDE

Mol. Wt.:

149.66

Formula:

SnP

Synonyms:

Tin monophosphide

Tin phosphide

M.P.:

Decomposes (79)

Characteristics:

Solid - silver white

crystal (79)

d./sp. gr.:

6.56 (79)

B.P.:

Decomposes (79)

Unique conditions, reaction products:

Reacts with moisture to yield phosphine (195).

Solubility:

d. hot H_2O (79)

(k) SILICIDES

CESIUM SILICIDE

Mol. Wt.:
161.0

Formula:
CsSi

Characteristics
Solid - brittle brass colorless
compact mass (80)

Flammability:

Ignites explosively on contact with H_2O or dilute acid (80).

POTASSIUM SILICIDE

Mol. Wt.:
67.2

Formula:
KSi

Characteristics
Solid - hard, poorly crystallized,
dark luster (80)

Synthesis

Pass potassium vapor over heated silica, forms potassium silicide and silicate (131).

Flammability:

Spontaneously flammable with detonation (50); ignites spontaneously on contact with water or dilute acids (80).

LITHIUM SILICIDE

Mol. Wt.:
97.81

Formula:
Li6Si2

M.P.:
d. $600^{\circ}C$ vac (79)

Characteristics
Solid - black crystals,
hygroscopic (79)

d./sp. gr.:
About 1.12 (79)

Synthesis

Heat silicon and lithium in vacuo for 2 or 3 hours, and finally at dull redness. Remove excess lithium with liquid NH_3 or distill off at $400^{\circ}-500^{\circ}C$ at reduced pressure (131)

Unique conditions, reaction products

Evolves spontaneously flammable gas as result of violent reaction with water (143).

Solubility:

d. hot and cold H_2O ; d. alcohol; i. NH_3 , turpentine (79)

SODIUM SILICIDE

Mol. Wt.:

51.1

Formula:

$NaSi$

Flammability:

Spontaneously flammable as loose powder (50); spontaneously flammable and explosive with H_2O or dilute acid (80).

(1) SULFIDES

BARIUM SULFIDE

Mol. Wt.:
169.43

Formula:
BaS

M.P.:
1200°C (79)

Characteristics:
Solid - colorless cubic
crystals (79)

d./sp. gr.:
4.2515 (79)

$\frac{n_D}{D}$
2.155 (79)

Toxicity:

Acute; excess salivation, vomiting, cholc, violent diarrhea, convulsive tremors, increased blood pressure and hemorrhages in GI tract and kidneys, also muscular paralysis (190).

Synthesis:

(1) reduce sulfate with coal; (2) melt is lixiviated with hot H₂O filtered and evaporated (190)

Unique conditions, reaction products:

With damp air decomposes to carbonate with evolution of H₂S (132).

Solubility:

d. in hot and cold H₂O; i. alcohol (79)

Flammability:

Moderate fire hazard, may ignite due to air, moisture or acid fumes (27)

CARBON DISULPHIDE

Mol. Wt.:
76.14

Formula:
CS₂

Synonyms:
Dithiocarbonic anhydride
Carbon bisulphide

M.P.:
111°C (79)

Characteristics:
Liquid - colorless (79)

V.P.:
40028 (195)

d./sp. gr.:
1.26122₂₀ (79)

B.P.:
46.3°C (79)

V.d.:
2.64 (195)

$\frac{n_D^{18}}{D}$
1.62950 (79)

Toxicity:

Highly toxic when ingested, inhaled or absorbed, acutely and chronically affects central nervous system; anaesthetic effect with death following respiratory failure (195); threshold limit value - 10 ppm (142).

Synthesis

React sulphur vapors and glowing carbon in electric furnace (214).

Unique conditions, reaction products

Decomposes to yield highly toxic fumes of sulphur oxides (195).

Ignition temperatures

flash point: -22°F (195)

autoignition temperature: 257°F (195)

Solubility

s. alcohol; inf. s. ether (79)

Handling

Ship in small glass or metal containers packed in fiber or protected from physical damage, isolate storage away from direct sunlight, keep cool (vapor pressure down) under H₂O and no nearby electrical installations (142).

Thermodynamic properties

heat of fusion (at -111.99°C): 1049 ± 3 cal/mol

heat of combustion: -246.6 kcal/mol

critical temperature: 273.05°C

critical pressure: 72.868 atm

free energy of formation (at 298.1°K): 15,160 cal/mol

(177)

Military and industrial uses

Important solvent (dissolves sulphur, rubber, iodine and potassium) also a fumigant, disinfectant and is used in preparation of CCl₄ (214).

CALCIUM SULPHIDE

Mol. Wt.:

72.14

Formula:

CaS

Synonym:

Natural oldhamite

M.P.:

Decomposes (79)

Characteristics

Solid - colorless cubic (79)

d./sp. gr.:

2.5 (79)

n

D_D

2.137 (79)

Synthesis

(1) strongly heat pulverized calcium sulphate with charcoal (190)

(2) CaCO₃ + H₂S → CaS + H₂O + CO₂ (80)

Solubility

s. alcohol; sl. s. cold H₂O, hot H₂O (132); d. acid (79)

Flammability

Air hazardous solid (27).

IRON SULFIDE

Mol. Wt.:
87.91

Formula:
FeS

Synonyms:
Ferrous sulfide
Nattrollite

M.P.:
1193-1199°C (79)

Characteristics:
Solid - black brown
hexagonal (79)

d./sp. gr.:
4.74 (79)

B.P.:
Decomposes (79)

Synthesis:

$\text{Fe} + \text{S} \rightarrow \text{FeS}$; seal Fe and S in quartz tube evacuated at high pressure, heat for 24 hours at 1000°C (higher and the tube bursts) reaction complete when and if S no longer collects at that end of hot tube when cooled for test purposes (80).

Solubility:

d hot H_2O ; sl. d. acid; i. NH_3 (79)

Flammability:

Spontaneously flammable (211).

POTASSIUM SULFIDE

Mol. Wt.:
110.27

Formula:
 K_2S

Synonyms:
Potassium sulfuret

M.P.:
471°C (195)
912°C (80)

Characteristics:
Solid - yellow brown
deliquescent cubic (79)

d./sp. gr.:
1.805¹⁴ (79)

Synthesis:



Solubility:

s. cold H_2O , acid, glycerol; v. s. hot H_2O ; i. ether (79)

Flammability:

Air hazardous, moisture hazardous, may ignite spontaneously (27).

SODIUM SULFIDE

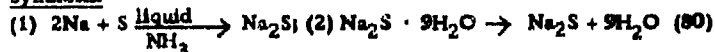
Mol. Wt.:
78.04

Formula:
 Na_2S

Synonyms:
Sodium monosulfide

M.P.:

1180°C (79)

CharacteristicsSolid - white deliquescent
crystals (79)d./sp. gr.:1.852¹⁴ (79)SynthesisSolubility:s. H₂O; sl. s. alcohol; d. acid; l. ether (79)Military and industrial uses:

Powerful reducing agent (214).

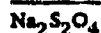
Flammability:

Air hazardous substance, moisture hazardous, spontaneously flammable in air (80).

SODIUM HYDROSULPHITE

Mol. Wt.:

174.10

Formula:Synonyms:Sodium dithionite
Sodium sulfoxylateM.P.:

d. 55°C

CharacteristicsSolid - white, grayish white
crystalline powder (195)Synthesis

Dissolve Zn in solution of sodium bisulfite; Zn—NaS₂ is precipitated by milk of lime leaving the hydrosulfite in solution, add salt and hydrosulfite of crystallization is precipitated, the latter is removed by treating with hot alcohol (190).

Solubility:v. s. H₂O; sl. s. alcohol (132)Military and industrial uses:

Used as reducing agent, particularly in dyeing with indigo and vat dyes, bleaching soaps and straw (132)

Flammability:

Oxidizes in air, with moisture becomes damp and is liable to ignite (15).

PHOSPHORUS SESQUISULFIDE

Mol. Wt.:

220.09

Formula:Synonyms:Phosphorus tetrakisulfide
Tetraphosphorus trisulfideM.P.:

172.5°C (195)

Characteristics

Solid - yellow rhombic (79)

d./sp. gr.:
2.0317 (79)

B.P.:
407°C (195)

Toxicity:

Probably toxic (195).

Synthesis:



Ignition temperature:

Autoignition temperature: 212°F (195)

Solubility:

1. cold H₂O; d. hot H₂O (79)

Handling:

Ship in glass jars and bottles, wooden cases, steel drums; protect from physical damage, store in cool ventilated place, separate from other material (142).

Military and industrial uses:

Used in matches manufacture to replace phosphorus and in synthetic organic chemistry (214).

PHOSPHORUS PENTASULFIDE

Mol. Wt.:
222.27

Formula:
P₂S₅

M.P.:
286°-290°C (79)

Characteristic:
Solid - gray yellow
deliquescent crystal (79)

d./sp. gr.:
2.03 (79)

B.P.:
514°C (79)

V.d.:
7.67 (131)

Toxicity:

Yield poisonous H₂S if react with H₂O, threshold value of dust 1 mg/m³ (142).

Synthesis:



Ignition temperature:

287°F (143)

Autoignition temperature: 548.6°F (195)

Solubility:

1. cold H₂O; d. hot H₂O; s. alkaline solvent, .22CS₂ (79)

Handling:

Ship in glass bottles, sealed drums, protect from physical damage and moisture, separate from oxidizing materials (142).

Military and industrial uses

Used in safety matches, ignition compounds, and for introducing sulfur into organic compounds (132).

Flammability:

Heats spontaneously, may ignite in presence of moisture (142).

THORIUM OXYSULFIDE

Mol. Wt.:

280.10

Formula:

ThOS

M.P.:

Decomposes (79)

Characteristics:

Solid - yellow crystals (79)

d./sp. gr.:

6.44 (79)

Solubility:

i. cold H_2O ; s. aqua regia; sl. s. HNO_3 (79)

Flammability:

Spontaneously flammable in air (143)

(m) MISCELLANEOUS

HEXAMMINO CALCIUM

Mol. Wt.:
142.08

Formula:
 $\text{Ca}(\text{NH}_3)_6$

Flammability:

Spontaneously flammable (50).

CHLOROSULFONIC ACID

Mol. Wt.:
116.52

Formula:
 ClSO_2OH

M.P.:
-80°C (79)

Characteristics:
Liquid - colorless, fuming,
pungent odor (79)

d./sp. gr.:
1.766¹⁸ (79)

B.P.:
158°C (79)

$\frac{n_{\text{D}}^{20}}{d_4^{20}}$
1.437 (79)

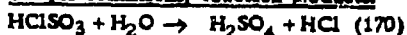
Toxicity:

Breaks down to HCl and H_2SO_4 with moisture in lungs (142); may produce severe acid burns, irritating to eyes, lungs, and mucous membranes, on ingestion seriously irritates mouth, esophagus and stomach, (195).

Synthesis:

- (1) pass HCl into fuming $\text{H}_2\text{SO}_4 \rightarrow \text{ClSO}_2\text{OH}$ (214)
- (2) react $\text{SO}_3 + \text{HCl} \rightarrow \text{ClSO}_2\text{OH}$ (214)

Unique conditions, reaction products:



Solubility:

d. to H_2SO_4 and HCl in cold H_2O (79); d. alcohol acid; i. CS_2 (79)

Handling:

Keep tightly closed, decomposes with explosive violence in H_2O (132).

Military and industrial uses:

Used in manufacture of organic sulfonic chlorides, sulfonating agent for hydroxyl compounds (214).
Used by German army in World War I for smoke screens (24).

Flammability:

Fumes with air (170)

IRON (II) HYDROXIDE

Mol. Wt.:
89.86

Formulas
 $\text{Fe}(\text{OH})_2$

M.P.:
Decomposes (79)

Characteristics
Solid - nearly white (slightly
greenish) hexagonal or white amorphous (79)

d./sp. gr.:
3.4 (79)

Synthesis

Carry on in N_2 atmosphere (absence of O_2) a centrifuged solution of $\text{Fe}(\text{OH})_2$ (precipitated from pure FeCl_2) in concentrated aqueous solution of NH_3 is admitted through a filter diluted with H_2O . Heat the $\text{Fe}(\text{OH})_2$ precipitate 3 hours at 80°C and allow precipitate to settle, wash in similar fashion. Solidify residue by immersion of flask in ice, salt mixture and distill off H_2O as solid slowly melts, complete drying with P_2O_5 under high vacuum (80).

Unique conditions, reaction products

When sprayed into air, burns with sparks (80).

Solubility:

cold H_2O .0001516, acid, NH_4Cl i. alkaline solvent (79)

POTASSIUM CHLORATE

Mol. Wt.:
122.55

Formulas
 KClO_3

M.P.:
 356°C (79)

Characteristics
Solid - colorless monoclinic (79)

d./sp. gr.:
2.32 (79)

B.P.:
d. 400°C (79)

$\frac{n_D}{D_1}$
1.409; 1.517; 1.524 (79)

Synthesis

- (1) electrolysis of a hot concentrated alkaline solution of KCl (190)
- (2) interaction of solutions of potassium chloride and sodium chlorate or calcium chlorate (190)

Solubility:

7.1²⁰ cold H_2O ; 57¹⁰⁰ hot H_2O ; 14.1¹⁰⁰ 50% alcohol; sl. s. glycol, liquid NH_3 ; i. acetone; s. alkaline solvent (79).

Military and industrial uses:

Explosive, fireworks, matches, printing and dyeing cotton and wool black, source of O_2 , in chemical analysis (190).

Flammability:

Spontaneously explosive (164).

DIPOTASSIUM NITROACETATE

Mol. Wt.:
181.2

Formula:
 $K_2(NO_2)CHCOO$

Unique conditions, reaction products

Exploded when dry salt moistened with a little H_2O (143).

MAGNESIUM CYANIDE

Mol. Wt.:
76.31

Formula:
 $Mg(CN)_2$

M.P.:
d. $300^\circ C$ to $MgCN_2$ (79)

B.P.:
d. $600^\circ C$ (79)

Solubility:
s. cold H_2O ; d. hot H_2O (79)

Flammability:

Liable to produce fire upon exposure to air (27).

SODIUM HYDROXYLAMINE

Mol. Wt.:
53.99

Formula:
 $NaNH_2O$

Synthesis

Sodium reacts incandescently with hydroxylamine in ethereal solution yielding hydrogen and NH_2ONa (131).

Flammability:

Spontaneously flammable in air (143).

SODIUM HYDRAZIDE

Mol. Wt.:
53.99

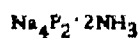
Formula:
 $NaNHNH_2$

Synthesis

Thin slices pure sodium gradually added to ordinary free hydrazine in an atmosphere of pure dry nitrogen, a colorless precipitate is formed ($NaOH$) and liquid becomes yellow, evaporate yellow solution and $NaNHNH_2$ remained as residue (131).

Unique conditions, reaction products

Can explode with air, alcohol, or moisture (142).



Mol. Wt.:
187.90

Unique conditions, reaction products

Violent reaction with H_2O yields spontaneously flammable phosphine and hydrogen (156).

DIAMIDOPHOSPHORUS ACID

Mol. Wt.:
95.99

Formulas
 $(\text{NH}_2)_2\text{P}(\text{O})\text{OH}$

Synthesis

Treat phenyldichlorophosphate $\text{Cl}_2\text{P}(\text{O})\text{OC}_6\text{H}_5$ with NH_3 to convert it into phenyldiamidophosphate, and $(\text{NH}_2)_2\text{POOC}_6\text{H}_5$ and hydrolyze the product with a solution of potassium diamidophosphate. Heat the cold solution of this salt with CH_3COOH to form crystals of $(\text{NH}_2)_2\text{POOH}$ (131).

RUBIDIUM SILICIDE

Mol. Wt.:
113.5

Formulas
 RbSi

Characteristics

Solid - small dark crystals (80)

Unique conditions, reaction products

Ignites explosively on contact with H_2O or dilute acids (80).

PROSILOXANE

Mol. Wt.:
46.09

Formulas
 H_2SiO

Flammability:

Spontaneously flammable in air (143).



Mol. Wt.:
118.18

Synthesis



Flammability:

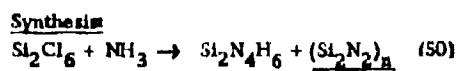
Spontaneously flammable (50).

SILICOCYN

Mol. Wt.:
(84.18)_n

Formula:
(Si₂N₂)_n

Synthesis



Flammability:

Spontaneously flammable (50)

TITANIUM BORIDE

Mol. Wt.:
69.54

Formula:
TiB₂

Synthesis

Prepared from titanium powder and boron trichloride under argon (24).

Flammability:

Spontaneously flammable (240).

II. ORGANIC COMPOUNDS

(a) METAL

PHENYLSILVER

Mol. Wt.:

184.98

Formula:

$(C_6H_5)Ag$

M.P.:

d. $-18^\circ C$ (103)

Characteristics:

Powder - gray or brown (103)

Synthesis:

Precipitates when AgCl or AgBr is added to a cooled solution of phenylmagnesium bromide (41).

Solubility:

s. ether; i. organics (103)

Flammability:

Explosive at room temperature (41)

ETHYL DICHLOROALUMINE

Mol. Wt.:

126.96

Formula:

$C_2H_5AlCl_2$

Synonyms:

Ethyl aluminum dichloride

M.P.:

$22^\circ C$ (226)

Characteristics:

Liquid - yellow (226)

V.P.:

1280

30100

69120

280168

575180

(226)

d./sp. gr.:

1.23225

B.P.:

$194^\circ C$ (extrapolated) (226)

Viscosity:

3.18 (at $23.3^\circ C$) (226)

Synthesis:

Reaction of aluminum chloride with ethyl aluminum sesquichloride (190)

Unique conditions, reaction products:

Violent reaction with H_2O (190)

Solubility:

d. H_2O , air (226)

Military and industrial uses:

Catalyst for olefin polymerization and aromatic hydrogenation (190).

Flammability:

Spontaneously flammable (226).

ALUMINUM BOROHYDRIDE MIXTURE

Mol. Wt.:

117.46

Formulas

$\text{Al}(\text{BH}_4)_3 \cdot \text{C}_2\text{H}_6\text{O}$

Flammability:

Spontaneously ignites at room temperature after a short induction period (173).

TRIMETHYL ALUMINUM

Mol. Wt.:

72.02

Formulas

$(\text{CH}_3)_3\text{Al}$

Synonyms

Trimethyl alumine

M. P.:

15.4°C (226)

Characteristics

Liquid - colorless (226)

V. P.:

8.4°C
68.560
332.100 } (226)

B. P.:

126°C (226)

Synthesis

(1) $2\text{Al} + 3(\text{CH}_3)_2\text{Hg} \rightarrow 2(\text{CH}_3)_3\text{Al} + 3\text{Hg}$ (109)

(2) $\text{Al}_2\text{Mg}_3 + 6\text{CH}_3\text{Cl} \rightarrow 2(\text{CH}_3)_3\text{Al} + 3\text{MgCl}_2$ (109)

Unique conditions, reaction products

Violent reaction with H_2O and oxidizing materials (109)

Solubility

s. organics; d. H_2O , air (226)

Thermodynamic properties

enthalpy of combustion: 762.1 ± 2.3 kcal/mol (714)

enthalpy of formation (liq) -28.2 kcal/mol (714); (gas) -13.3 kcal/mol (714)

heat of combustion: 10,500 cal/g (226)

specific heat (at 33 mm): .53 (226)

Military and industrial uses

If released in atmosphere, produces self luminous trails useful for wind measurements, wind shears, and turbulence at night (192); intermediate class of propellants (109).

Flammability

Spontaneously flammable (226).

TRIMETHYL ALUMINUM BROMIDE

Mol. Wt.:

231.85

Formulas

$(\text{CH}_3)_3\text{AlBr}_2$

Characteristics

Liquid (130)

Flammability

Pyrophoric (130)

DIETHYL ALUMINUM BROMIDE

Mol. Wt.:
164.94

Formula:
(C₂H₅)₂AlBr

B.P.:
383°F (126)

Characteristics:
Liquid (126)

Unique conditions, reaction products:
Ignites with air, H₂O, alcohol (126).

DIETHYL CHLOROALUMINE

Mol. Wt.:
120.56

Formula:
(C₂H₅)₂AlCl

Synonyms:
Diethyl aluminum chloride

M.P.:
-74°C (226)

Characteristics:
Liquid - colorless (226)

V.P.:
141
1290
65130 } (226)
256170
465170

d./sp. gr.:
.95825 (226)

B.P.:
208°C (226)
(extrapolated)

Viscosity:
.453 cp (at 23.3°C) (226)

Toxicity:
Produces deep painful burns on contact with living tissue (142).

Synthesis:
React triethyl aluminum with ethyl aluminum sesquichloride (190).

Unique conditions, reaction products:
Violent reaction with H₂O (190).

Handling:
Ship in steel cylinders, store in isolated, well ventilated, fire resistive storeroom. Protect containers from shock and damage (142).

DIETHYL ALUMINUM HYDRIDE

Mol. Wt.:
86.11

Formula:
(C₂H₅)₂AlH

Synonyms:
Diethyl alumine

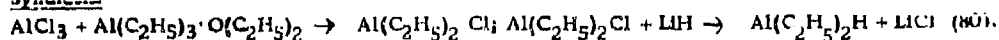
d./sp. gr.:
.80820 (103)

Characteristics:
Liquid - colorless (103)

V.P.:
55-56 .001-.0001 (103)

n_D²⁰:
1.4702 (103)

Synthesis



Solubility

d. H_2O , air (103)

Flammability

Spontaneously ignites in air (145).

TRIMETHYL ALUMINE DIMETHYL ETHER

Mol. Wt.:

118.11

Formula:



M.P.:

-30°C (226)

Characteristics

Liquid (226)

B.P.:

159°C (226)

Solubility

s. organics; d. H_2O (226)

Flammability

Spontaneously flammable (226).

TRIETHYL ALUMINUM

Mol. Wt.:

114.17

Formula:



M.P.:

-46°C (226)

Characteristics

Liquid - colorless (226)

V.P.:

.00448-50 } (226)
.860
1310
110140

d./sp. gr.:

.832425 (226)

M.P.:

194°C (226)
207°C (extrapolated) (226)

Specific heat

.527 (at 33 mm)

n_D²⁰

1.480 (226)

Viscosity

2.58 cp (at 25°C) (226)

Toxicity

H₂, extremely destructive to living tissue (80).

Synthesis

$\text{Al}(\text{C}_2\text{H}_5)_2\text{Br} + \text{Na}(\text{wire}) \rightarrow \text{Al}(\text{C}_2\text{H}_5)_3$... Heat flask of $\text{Al}(\text{C}_2\text{H}_5)_2\text{Br}$ and Na wire at 105°C (with external cooling) until reaction calms, add more $\text{Al}(\text{C}_2\text{H}_5)_2\text{Br}$ and heat to 200°C for 10 hours with stirring, cool flask and add extra Na wire to ensure dehalogenation completion, resume stirring at 150°C for 1½ hours. Distill off $\text{Al}(\text{C}_2\text{H}_5)_3$ (80).

Unique conditions, reaction products

Hydrolyzes to $\text{Al}(\text{OH})_3$ immediately with moisture (80); explodes violently with H_2O (143).

Ignition temperatures

flash point: $< -52.5^{\circ}\text{C}$ (195)

autoignition temperature: $< -52.5^{\circ}\text{C}$ (195)

Solubility:

s. organics; decomposes H_2O , air (226).

Military and industrial uses

Used in experimental tests for obtaining heat transfer parameters (73); igniter for rocket fuels (187); igniter for capsule firing flame thrower (98).

Flammability:

Spontaneously flammable (226).

DI-n-PROPYLALUMINUM HYDRIDE

Mol. Wt.:

114.04

Formulas

$(\text{C}_3\text{H}_7)_2\text{AlH}$

Flammability:

Ignites spontaneously in air (145).

TRIMETHYL ALUMINE-DIETHYL ETHER

Mol. Wt.:

146.21

Formulas

$(\text{CH}_3)_3\text{Al} \cdot \text{O}(\text{C}_2\text{H}_5)_2$

Characteristics

Liquid (226)

V. P.:

1568 (226)

Solubility:

s. organic solvent; d. H_2O (226)

Flammability:

Spontaneously flammable (226).

DIISOBUTYL ALUMINUM CHLORIDE

Mol. Wt.:

176.67

Formulas

$\text{AlCl}(\text{iso-C}_4\text{H}_9)_2$

Synonyms

Di-i-butylchloroalumine

M. P.:

-39.5°C (103)

Characteristics

Liquid - colorless (103)

V. P.:

10152
5138
1108 } (103)

d./sp. gr.:

.9088²⁰₂₀ (103)

n_D²⁰

1.4506 (103)

Viscosity:

5.11 cps (at 20°C) (103)

Unique conditions, reaction products

Yields dense white smoke on reaction with H_2O : $AlCl(iiso-C_4H_9)_2 + H_2O \rightarrow Al(OH)_2Cl + 2iso-C_2H_{10}$ (111).

Solubility

s. organic solvents; d. H_2O (103)

Flammability

High spontaneous exothermic reaction (may flame) on contact with air (111).

DIISOBUTYL ALUMINUM HYDRIDE

Mol. Wt.:

142.06

Formula:

$(i-C_4H_9)_2AlH$

B.P.:

105°C (190)

Synthesis

Reaction of isobutylene and hydrogen with aluminum (190).

Military and industrial uses

Reducing agents in the manufacture of pharmaceuticals (190)

Flammability

Pyrophoric liquid (190).

TRIPROPYLALUMINUM

Mol. Wt.:

156.25

Formula:

$(n-C_3H_7)_3Al$

M.P.:

-107°C (103)

Characteristics

Liquid - colorless (103)

d./sp. gr.:

.823²⁰ (103)

B.P.:

248-252°C (103)

V.P.:

1565 (103)

Toxicity

Slight (acute local) as irritant, or allergen; slight (chronic local) as allergen (195).

Unique conditions, reaction products

Vigorous reaction with oxidizing materials, hydrolyzes to evolve flammable vapors (195); explodes violently with H_2O (143).

Solubility

s. organic solvents; d. H_2O (103).

Flammability

Pyrophoric (190).

TRIPROPYL ALUMINUM

<u>Mol. Wt.</u> 156.25	<u>Formula</u> $(i-C_3H_7)_3Al$	<u>Synonyms</u> Isopropylaluminum
<u>M.P.</u> -107°C (103)	<u>Characteristics</u> Liquid - colorless (103)	<u>V.P.</u> 1565 (103)
<u>d./sp. gr.</u> .82320 (103)	<u>B.P.</u> 248-252°C (103)	

Solubility

s. organic solvents; d. H_2O (103).

Flammability

Spontaneously flammable (168).

DIETHYL 4-ETHOXY BUTYLAMINE

<u>Mol. Wt.</u> 186.27	<u>Formula</u> $(C_2H_5)_2Al(CH_2)_4OC_2H_5$	
	<u>Characteristics</u> Liquid - colorless (226)	<u>V.P.</u> 5.5 ⁹⁹ .5 (226)

Solubility

d. air; s. organic solvents (226)

Flammability

Spontaneously flammable (226).

TRIETHYL ALUMINE DIETHYL ETHER

<u>Mol. Wt.</u> 188.25	<u>Formula</u> $Al(C_2H_5)_3(C_2H_5)_2O$	<u>B.P.</u> 216°-218°C (226)
<u>n_D^{17.4}</u> 1.4370 (226)	<u>Characteristics</u> Liquid - colorless (226)	<u>V.P.</u> 16112 (226)

Flammability

Spontaneously flammable (226)

DIETHYLDIETHYL AMINO-3-PROPYL ALUMINE

<u>Mol. Wt.</u> 199.32	<u>Formula</u> $(C_2H_5)_2Al(CH_2)_3N(C_2H_5)_2$
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<u>M.P.:</u>	<u>Characteristics</u>	<u>V.P.:</u>
-2°C (226)	Liquid - straw (226)	297 (226)

Solubility
s. organic solvents; d. air (226)

Flammability
Spontaneously flammable (226)

TRI-n-BUTYLALUMINUM

<u>Mol. Wt.:</u>	<u>Formula:</u>
198.33	(n-C ₄ H ₉) ₃ Al
	<u>Characteristics</u>
	Liquid - colorless (190)

Synthesis
Exchange reaction between butene-1 and isobutyl aluminum (190)

Military and industrial uses
Production of organotin compounds (190).

Flammability
Pyrophoric (190)

TRI-iso-BUTYLALUMINUM

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
198.3	(C ₄ H ₉) ₃ Al	Triisobutylaluminum
<u>M.P.:</u>	<u>Characteristics</u>	<u>V.P.:</u>
1.0 - 4.3°C (103)	Liquid - colorless (103)	147 (103)
<u>d./sp. gr.:</u>	<u>n_D²⁰</u>	<u>Viscosity</u>
.7859 ²⁰ (103)	<u>D₄</u> 1.4404 (103)	2.39 cps (at 20°C) (103)

Toxicity
High, extremely destructive to living tissue (195).

Synthesis
React isobutylene and hydrogen with aluminum under moderate temperature and varying pressure (190)

Unique conditions, reaction products
Reacts violently with H₂O, acids, halogens, alcohols and amines (190).

Ignition temperatures
Flash points < 4°C (195)
autoignition temperatures < 4°C (195)

Solubility:

d. H_2O , air (103)

Military and industrial uses:

Polyolefin catalyst; manufacture of primary alcohols and olefins; pyrophoric fuel (190).

Flammability:

Fumes violently or ignites with air (190)

TRIPHENYLALUMINUM

Mol. Wt.:

258.30

Formula:

$(C_6H_5)_3Al$

M.P.:

230°C (103)

Characteristics:

Solid - white (103)

Solubility:

d. (explosively) H_2O ; s. organics (190)

1, 1, 1-TRIMETHYL TRIBROMO DIALUMINE

Mol. Wt.:

338.81

Formula:

$(CH_3)_3Al_2Br_3$

Synonyms:

Methyl aluminum sesquibromide

M.P.:

4°C

Characteristics:

Liquid - yellow (226)

V.P.:

1500

3980

89100

185120

359140

650180

(226)

d./sp. gr.:

1.51425 (226)

B.P.:

166°C (extrapolated) (226)

Viscosity:

2.76 cp (at 23.3°C) (226)

Unique conditions, reaction products:

Violent reaction with H_2O (190)

Solubility:

s. organic solvent; i. H_2O (226)

Military and industrial uses:

Catalyst for polymerization of olefins and hydrogenation of aromatics (226).

Flammability:

Spontaneously flammable (226).

METHYLALUMINUM SESQUICHLORIDE

Mol. Wt.:

205.34

Formula:

$(CH_3)_3Al_2Cl_3$

B.P.:

143.7°C (extrapolated) (190)

F.P.:

22.8°C (190)

d./sp. gr.:

1.62925 (190)

Military and industrial uses

Catalyst for polymerization of olefins and hydrogenation of aromatics (190).

Flammability:

Flames instantly in air (190).

1, 1, 2-TRIMETHYL DIALUMENE

Mol. Wt.:

102.09

Formula:

$(CH_3)_2HAIAIH_2CH_3$

Synonyms:

Trimethyl aluminum hydride

Unique conditions, reaction products

Vigorous reaction with $H_2O \rightarrow CH_4 + H_2 + Al_2O_3$ (92)

Solubility:

d. air, H_2O (226)

Flammability:

Spontaneously flammable (92)

1, 2-DIETHYL TETRAIDO DIALUMENE

Mol. Wt.:

619.72

Formula:

$C_2H_5)_2AlAl(C_2H_5)_2$

Synonyms:

Characteristics:

Liquid (226)

V.P.:

4158-160 (226)

Solubility:

d. H_2O (226)

Flammability:

Spontaneously flammable (226)

1, 1, 2, 2-TETRAMETHYL DIALUMENE

Mol. Wt.:

116.12

Formula:

$(CH_3)_2HAIAIH(CH_3)_2$

Characteristics:

Liquid - colorless (226)

B.P.:

Decomposes (226)

Unique conditions, reaction products

Reacts with H_2O to yield $CH_4 + H_2 + Al_2O_3$ (92).

Solubility:

s. organic solvents; d. H_2O (226)

Flammability:

Spontaneously flammable (92).

PENTAMETHYL DIALUMENE

Mol. Wt.:
130.14

Formula:
 $(CH_3)_3Al_2H(CH_3)_2$

Synonyms:
Pentamethyl aluminum hydride

Characteristics:
Liquid (226)

B.P.:
d. air (226)

Unique conditions, reaction products:

Reacts with H_2O to yield $CH_4 + H_2 + Al_2O_3$ (92)

Flammability:

Spontaneously flammable (92).

1, 1, 1-TRIETHYL TRICHLORODIALUMENE

Mol. Wt.:
247.52

Formula:
 $(C_2H_5)_3AlAlCl_3$

Synonyms:
Ethyl aluminum sesquichloride

M.P.:
-20°C (226)

Characteristics:
Liquid - yellow (226)

V.P.:
1490
34110
76130
525190 } (226)

d./sp. gr.:
1.09225 (226)

B.P.:
204°C (extrapolated) (226)

Viscosity:

1.91 cp (at 23.3°C) (226)

Synthesis:

Reaction of ethyl chloride and aluminum (190).

Unique conditions, reaction products:

Reacts violently with H_2O (190).

Military and industrial uses:

Catalyst for olefin polymerization and aromatic hydrogenation (190).

Flammability:

Spontaneously flammable (226).

TRIETHYL ALUMINUM ETHERATE

Mol. Wt.:
699.0 (79)

Formula:
 $4Al(C_2H_5)_3 \cdot 3(C_2H_5)_2O$

Characteristics:
Liquid - colorless (79)

B.P.:
11216 (79)

Unique conditions, reaction products:

Explodes with moisture evolving ethane; warming evolves copious fumes of ether (195).

Solubility

Explodes with cold H₂O (79).

Flammability

Explodes with moisture (195).

ALUMINUM SESQUIBROMIDE ETHYLATE

Characteristics

Liquid (125)

Unique conditions, reaction products

Explodes with decomposition on contact with H₂O or alcohol (125).

Flammability

Pyrophoric (125).

TRIETHYL ALUMINUM TRIETHYL BORON

Formulas

TEAB

[TEA + TEB]

15% 85%

Flammability

Pyrophoric (186).

DIMETHYLCHLOROARSINE

Mol. Wt.

140.44

Formulas

(CH₃)₂AsCl

Synonyms

Dimethylarsenic monochloride

Chlorodimethyl arsine

Cacodyl chloride

M.P.

< -45°C (79)

Characteristics

Liquid - colorless (79)

d./sp. gr.

1.5046₄¹² (79)

B.P.

109°C (79)

V.d.

4.84 (195)

n_D¹²

1.5203 (79)

Synthesis

Dissolve cacodylic acid in excess HCl and reduce with solution of hypophosphorus acid in the same reagent below 50°C. Cacodyl chloride separates as a heavy faint yellow oil which is removed in a separatory funnel, dried with CaCl₂ and distilled in a Cl₂ atmosphere (176).

Solubility:

s. alcohol; i. H₂O, ether (195).

Flammability:

Spontaneously flammable (226).

CACODYL FLUORIDE

Mol. Wt.:

123.94

Formula:

(CH₃)₂AsF

Characteristics:

Liquid - colorless (unbearable repulsive odor) (176)

Solubility:

i. H₂O (apparently decomposed by it) (176)

Handling:

Corrosive to glass, keep in platinum container (176).

Flammability:

Spontaneously flammable (227).

CACODYL IODIDE

Mol. Wt.:

231.89

Formula:

(CH₃)₂AsI

M.P.:

-35°C (solidification point) (176)

Characteristics:

Liquid (103); yellow oil (46)

B.P.:

154-155°C (103)

Synthesis:

(1) Aqueous solution of cacodylic acid and KI is saturated with SO₂; add 1:1 HCl from time to time. Cacodyl iodide separates as a yellow oil; (2) Methyl diiodoarsine and methyl iodide are permitted to react in alcohol concentrated aqueous caustic soda solution over night, solvent is distilled off, the residue is acidified with HCl and saturated SO₂; (3) Cacodyl chloride is gradually added to a solution of sodium iodide in dry acetone and the resulting solution permitted to stand for several hours in a CO₂ atmosphere, filter and distill off acetone from filtrate, take residue up with ether, remove the solvent from the extract by distillation and rectify residue in CO₂ atmosphere (176).

Solubility:

i. H₂O (176); s. organic solvent (103).

Flammability:

Spontaneously flammable (227).

DIMETHYL ARSINE

Mol. Wt. :
105.99

Formula:
 $(\text{CH}_3)_2\text{AsH}$

d./sp. gr.:
1.213²⁹₂₉ (79)

Characteristics
Liquid - colorless (226)

V.P.:
1.213²⁰ (226)
1.210²⁵

B.P.:
35.6-37.0°C (226)

Toxicity
High (195).

Synthesis

Add concentrated HCl slowly to a round bottom flask containing zinc dust, cacodyl oxide and alcohol. The generator is joined in series with an H_2O wash bottle, a U-tube filled with soda lime, a bulk condenser for dimethyl arsine surrounded with ice and salt and 2 wash bottles (H_2SO_4 and HNO_3). $[(\text{CH}_3)_2\text{As}]_2\text{O} + \text{H}_2 \rightarrow (\text{CH}_3)_2\text{As} \cdot \text{As}(\text{CH}_3)_2 + \text{H}_2\text{O}$; $(\text{CH}_3)_2\text{As} \cdot \text{As}(\text{CH}_3)_2 + \text{H}_2 \rightarrow 2(\text{CH}_3)_2\text{AsH}$ (176).

Solubility

s. organic solvent (226); ∞ alcohol, ether, chloroform, carbon disulfide, acetic acid (79).

Flammability

Spontaneously flammable (226).

CACODYL CYANIDE

Mol. Wt.:
131.01

Formula:
 $(\text{CH}_3)_2\text{AsCN}$

M.P.:
33°C (79)

Characteristics
Powder - lustrous
colorless (79)

B.P.:
140°C (79)

Toxicity

High (with slight amount in air); on inhalation causes numbness of extremities, giddiness, stupor and unconsciousness (no prolonged after effects) (176).

Synthesis

- (1) $[(\text{CH}_3)_2\text{As}]_2\text{O} + 2\text{HCN} \xrightarrow{\text{distill}} 2(\text{CH}_3)_2\text{AsCN} + \text{H}_2\text{O}$ (contaminant of $[(\text{CH}_3)_2\text{As}]_2\text{O}$ hard to remove) (176)
- (2) $[(\text{CH}_3)_2\text{As}]_2\text{O} + \text{Hg}(\text{CN})_2 \rightarrow 2(\text{CH}_3)_2\text{AsCN} + \text{Hg}$ (176)
- (3) $[(\text{CH}_3)_2\text{As}]_2\text{O} + (\text{dry with 5 times calculated amount}) \text{HCN} \xrightarrow[\text{sealed tube}]{\Delta} (\text{CH}_3)_2\text{AsCN}$ (use CO_2 current to remove excess HCN) (176)

Solubility

sl. s. cold H_2O ; s. alcohol, ether (79)

Flammability:

Spontaneously flammable (227).

METHYLETHYLIODOARSINE

Mol. Wt.:
245.86

Formulas
 $(CH_3)(C_2H_5)AsI$

Characteristics
Liquid - yellow oil (176)

B.P.:
65¹⁴ (176)

Synthesis

Reflux aqueous caustic alkaline solution of ethylaliodoarsine for a few hours with CH_3I , the solution is then neutralized, freed from alcohol, acidified with HCl and finally saturated with SO_2 (176).

Unique conditions, reaction products

Slight decomposition on boiling (176).

Flammability:

Occasionally ignites spontaneously at ordinary temperatures (176).

ETHYL METHYL ARSINE

Mol. Wt.:
119.95

Formulas
 $HAs(CH_3)(C_2H_5)$

B.P.:
71°C (52)

Flammability:

Ignites spontaneously in air (52).

ARSENIC TRIMETHYL

Mol. Wt.:
120.03

Formulas
 $As(CH_3)_3$

Synonyms:
Trimethyl arsine

M.P.:
-87.3°C (103)

Characteristics
Liquid - colorless

V.d.:
4.14 (195)

d./sp. gr.:
1.124²² (103)

n_D²⁰
1.4541 (103)

Surface tension
20.4 dynes/cm (at 20°C) (103)

Synthesis

(1) distill tetramethyl arsonium iodide (or its double salt) with solid KOH ; (2) distill ethyl magnesium iodide and arsenic tribromide in ether solution; (3) distill zinc dimethyl and arsenic trichloride; or (4) heat crude cacodyl for 2 hours at 340°C in a sealed tube filled with CO_2 (176).

Solubility:

sl. s. H_2O (103)

Thermodynamic properties

heat of combustion: 5510.2-5576.4 cal/g
enthalpy of combustion: 664.6 ± 1.2 kcal/mol
enthalpy of formation (liq) 3.5 kcal/mol; (gas) 10.6 kcal/mol
heat of vaporization: 6600 cal/mol (103)

} (114)

Flammability:

Flames spontaneously in air (143)

DIETHYL ARSINE

Mol. Wt.:
134.05

Formula:
 $(C_2H_5)_2AsH$

d./sp. gr.:
1.388²⁴ (226)

Characteristic
Liquid - colorless (226)

B.P.:
105 96.5 - 97 (226)

n_D²⁵
1.4709 (226)

Solubility
s. H₂O (226)

Flammability:

Spontaneously flammable (226)

DIMETHYL ALLYL ARSINE

Mol. Wt.:
87.93

Formula:
 $CH_2=CH-CH_2-As-(CH_3)_2$

Characteristic
Liquid - pale yellow (176).

B.P.:
108-110°C (52)

Synthesis

From dimethyl arsine and allyl iodide (176).

Unique conditions, reaction products

With bromine in ether solution yields the corresponding arsine dibromide (176).

Flammability:

Ignites in air and on filter paper (52)

ARSENIC TRIETHYL

Mol. Wt.:
162.11

Formula:
 $As(C_2H_5)_3$

Synonyms
Triethyl arsine

<u>d./sp. gr.:</u> 1.150 ²⁰ ₄ (103)	<u>Characteristics</u> Liquid - colorless (103)	<u>V.P.:</u> 1536.5 - 37 (103)
<u>B.P.:</u> 140 ⁷³⁶ (sl.d.) (103)	<u>n_D²⁰</u> 1.4751 (103)	<u>V.d.:</u> 5.59 (195)
	<u>n_D²⁵</u> 1.4670 (103)	<u>Surface tension:</u> 25.2 dynes/cm (at 20°C) (103)

Toxicity:
High. (195)

Synthesis

(1) react arsenic trichloride with zinc diethyl; (2) distill tetraethylarsenium iodide (or its double salt) and (C₂H₅)₄AsI·AsI₃ with solid caustic potash (176).

Solubility:

i. H₂O; ∞ alcohol ether (103)

Thermodynamic properties

heat of combustion 7129 ± 13 cal/g
enthalpy of combustion 1158.2 ± 2.0 kcal/mol
enthalpy of formation (gas) 13.4 kcal/mol; (liq) 3.1 kcal/mol } (114)

Flammability:

Spontaneously flammable in air (143).

CACODYL

<u>Mol. Wt.:</u> 209.94	<u>Formula:</u> (CH ₃) ₂ AsAs(CH ₃) ₂	<u>Synonyms:</u> Tetramethyl diarsine Diarsenic tetramethyl Dimethylarsine Dicacodyl Tetramethyldiarsyl
<u>M.P.:</u> -5°C (79)	<u>Characteristics:</u> Liquid - oily yellow (79)	
<u>d./sp. gr.:</u> 1.44715 (79)	<u>B.P.:</u> 163 ⁷⁶⁰ (79)	

Toxicity:
Very high (195).

Synthesis

(1) heat cacodyl chloride with zinc at 90-100°C in CO₂ atmosphere
(2) reduce cacodylic acid and HCl solution with hypophosphorus acid
(3) reduce cacodylic acid and 3NH₂SO₄ solution by electrolytic means } (176)

Unique conditions, reaction properties

If heated to decomposition emits arsenic fumes (195); flames spontaneously in chlorine (176)

Ignition temperature:

Flash point > 100°F (27)

Solubility:

s. alcohol, ether (69).

Flammability:

Spontaneously flammable in dry air (80)

CACODYL DIOXIDE

Formulas

$[(CH_3)_2As]_2O_2$

Characteristics

Liquid (195)

Handling:

Decomposes with heat to yield arsenic fumes (195).

Flammability:

Spontaneously flammable (195).

CACODYL SULFIDE

Mol. Wt.:

242.05

Formulas

$[(CH_3)_2As]_2S$

Synonyms

Tetramethyl diarsinthiane
Bisdimethylarsine sulfide
Dicacodyl sulfide

M.P.:

< -40°C (195)

Characteristics

Liquid - oily (79)

B.P.:

211°C (79)

Synthesis

(1) Pass H_2S through a concentrated alcoholic solution of cacodylic acid; (2) Distill cacodyl chloride with boron hydrosulfide; (3) Heat 2 moles dimethyl arsine with less than 1 mole sulfur in a sealed tube and allow to stand 2-3 days (176).

Unique conditions, reaction products:

If heated to decomposition it emits toxic arsenic and sulfur fumes (195).

Solubility:

sl. s. H_2O ; s. alcohol, ether (79)

Flammability:

Ignites spontaneously in air (195).

TETRAMETHYL DIARSINE

Mol. Wt.:

266.07

Formulas

$(C_2H_5)_2As_2(C_2H_5)_2$

d./sp. gr.:
1.2^{23.7} (226)

Characteristics
Liquid (226)

B.P.:
185°-190° C (226)

n_D²⁵
1.4709 (226)

Synthesis

Mix sodium arsenide with four to five times its weight of quartz sand and reflux with ethyl iodide in an atmosphere of CO₂, let the reaction finish and cool; extract with ether in CO₂ atmosphere and mix extract with absolute alcohol (176).

Solubility

l. H₂O; s. alcohol, ether (226).

Flammability

Spontaneously flammable (226).

PHENYL CACODYL

Mol. Wt.:
458

Formula:
(C₆H₅)₂As·As(C₆H₅)₂

Synonyms
Tetraphenyl diarsine

M.P.:
200 (103)

Characteristics
Crystal (103)

Synthesis

(1) Reflux alcoholic diphenylarsineoxide with an excess of phosphorous acid; (2) Heat alcoholic diphenylarsenic acid with a large excess of some reducing agent in a sealed tube for 10 hours at 100°C; (3) stir diphenylchloroarsine with phosphorous acid at 100°C (176).

Solubility

s. ethanol; sl. s. ethanone (103)

Flammability

Spontaneously flammable (50).

ETHYL BORON DICHLORIDE

Mol. Wt.:
110.71

Formula:
C₂H₅BCl₂

B.P.:
110° (207)

Synthesis

Heat triethylborane and boron trichloride for 4 hours at 200°C (204);
(C₂H₅)₃B + BCl₃ → C₂H₅BCl₂ + (C₂H₅)₂BCl (206-207)

Military and industrial uses

Preparation of borazoles (206-207)

Flammability

Spontaneously flammable (204).

TRIMETHYL BORON

<u>Mol. Wt.:</u>	<u>Formulas:</u>	<u>Synonyms:</u>
55.92	$B(CH_3)_3$	Trimethyl borine Boron trimethyl Boron methyl
<u>M.P.:</u>	<u>Characteristics:</u>	
-153.61.5 (226)	Gas - colorless (79)	
<u>d./sp. gr.:</u>	<u>B.P.:</u>	<u>V.P.:</u>
.63-100 (226)	-20°C (226)	80-50 (226)
1.9108		31-80

Synthesis

A grignard reaction of (Mg + n-butyl ether + CH_3Br) takes 6 hours for completion in an oxygen free nitrogen atmosphere, bubble nitrogen through the subsequent reaction, add BF_3 dropwise at $-78^\circ C$, warm to $70^\circ C$, in 2 hours the product condenses in cold traps. Purify product by high vacuum distillation at $78^\circ C$. Trap in receiver at $-124^\circ C$ or substitute ethyl ether for n-butyl ether and add BF_3 in form of diethyl etherate or bubble into grignard solution as a gas. Keep H_2SO_4 present between the condenser and the traps to absorb any ether present in product gas (80).

Solubility:

s. organic solvent; d. air (226)

Thermodynamic properties

heat of vaporization: 5.7 kcal/mol (226)

heat of combustion: 23,000 Btu/lb (226)

Flammability:

Spontaneously flammable (226).

BUTYL BORON DICHLORIDE

<u>Mol. Wt.:</u>	<u>Formulas:</u>	
138.84	$C_4H_9BCl_2$	
	<u>Characteristics:</u>	<u>B.P.:</u>
	Liquid (103)	3110 (204)
		88 (103)

Synthesis

Heat 14 moles of tributylborine for 20 hours at $200^\circ C$ with .31 moles of borine trichloride (204)
 $(n-C_4H_9)_3B + 2BCl_3 \rightarrow 3C_4H_9BCl_2$ (208).

Solubility:

s. organic solvent; d. H_2O (103)

Flammability:

Spontaneously flammable (204).

NOT REPRODUCIBLE

TRIBUTYL BORON DIFLUORIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>B.P.:</u>
105.84	$C_6H_9BF_2$	35 ⁷⁶⁰ (204)

Synthesis

Heat tributylborane and boron trifluoride for 24 hours at 200°C and 20 hours at 205°C (204).

Unique conditions, reaction products

Not pyrophoric but fumes strongly in air (204).

DIETHYL BORON CHLORIDE

<u>Mol. Wt.:</u>	<u>Formula:</u>	<u>Synonyms:</u>
104.40	$(C_2H_5)_2BOCl$	Diethylchloroborane
<u>M.P.:</u>	<u>Physical form:</u>	<u>B.P.:</u>
-84.6°C (103)	Liquid (103)	25100 (103)

Synthesis

Heat triethylborane and boron trichloride for 24 hours at 200°C (204).

$2(C_2H_5)_3B + BCl_3 \rightarrow (C_2H_5)_2BOCl + (C_2H_5)_2BCl + BCl_3$ (204)

Solubility:

s. organic solvents; d. H_2O (103)

Thermodynamic properties:

heat of vaporization: 7.9 kcal/mol (103)

Flammability:

Spontaneously flammable (204).

DIPROPYL CHLOROBORANE

<u>Mol. Wt.:</u>	<u>Formula:</u>	
132.45	$(C_3H_7)_2BOCl$	
	$[C_3H_7]_2[40]$	
<u>M.P.:</u>	<u>Physical form:</u>	<u>B.P.:</u>
< 125°C (226)	Colorless liquid (226)	127°C (226)
<u>d./sp. gr.:</u>		
.848 ²⁰ (226)		

Solubility:

s. organic solvents (226)

Flammability:

Spontaneously flammable (226).

TRIETHYL BORINE

Mol. Wt.:

98.00

Formula:

$B(C_2H_5)_3$

Synonyms:

Boron triethyl
Triethyl boron
Boron ethyl

M.P.:

-93°C (226)

Characteristics:

Liquid - colorless (226)

V.P.:

12.5° (226)

d./sp. gr.:

.686²⁰ (226)

n_D²⁰

1.4485 (226)

Viscosity:

.30 (at 77°F) (237)

B.P.:

95°C (226)

Synthesis:

Add an n-butyl ether solution of BF_3 dropwise to a solution of C_2H_5MgBr in n-butyl ether, after the reaction is completed the product is distilled at 95°C under N_2 (80).

Unique conditions, reaction products:

Emits toxic fumes when heated to decomposition (195).

Solubility:

s. organic solvents; d. air (226).

Thermodynamic properties:

heat of combustion 21,900 Btu/lb (226).

Military and industrial uses:

Igniter for rocket fuels (186); igniter for capsule flame thrower (99).

Flammability:

Ignites spontaneously at partial pressures below 1 mm at 0°C (226); spontaneously flammable in air (237).

DIBUTYL BORON CHLORIDE

Mol. Wt.:

160.5°C

Formula:

$(C_4H_9)_2BCl$

Synonyms:

Dibutyl chloroborane

Characteristics:

Liquid - colorless (103)

B.P.:

54.1° (210)

Synthesis:

Redistribution of 2 moles of tributylborane with one mole of boron trichloride (210).

Solubility:

s. organic solvents; d. H_2O (103)

Thermodynamic properties:

heat of formation (gas): -98.1 ± 2 kcal/mol (714)

heat of formation (liq): -110 ± 1.6 kcal/mol (714)

Military and industrial uses

Used in preparation of several borinates (210).

Flammability:

Spontaneously flammable (210).

TRIPROPYL BORON

Mol. Wt.:
140.1

Formula:
 $(C_3H_7)_3B$

M.P.:
-52.5°C (103)

Characteristics:
Liquid - colorless (195)

B.P.:
15720 (195)

d./sp. gr.:
.725 (195)

$n_{D^{22.8}}$
 D_4 (79)
1.4135

Solubility:

l. H_2O ; s. ether (195)

Flammability:

Spontaneously flammable (247).

PHENYL CYCLOTETRAMETHYLENE BORINE

Mol. Wt.:
144.02

Formula:
 $C_6H_5B(CH_2)_4$

Characteristics:
Liquid - colorless (226)

V.P.:
1185-87 (226)

Solubility:

s. organic solvent; d. air (226)

Flammability:

Spontaneously flammable (226).

TRI-n-BUTYLBORANE

Mol. Wt.:
182.16

Formula:
 $(C_4H_9)_3B$

M.P.:
-34°C (190)

B.P.:
170222 (190)

V.P.:
-120 (190)

d./sp. gr.:
.74725 (190)

$n_{D^{20}}$
 D_4 (190)
1.4285

Ignition temperature:
flash points: -82°F (190)

Solubility:
l. H_2O ; s. most organic solvents (190)

Handling:
Store, transfer or use in an inert atmosphere (dry nitrogen or argon) store in dry ventilated room at room temperature (190)

Thermodynamic properties
heat of vaporization (at 25°C): 2110 ± 10 kcal/mol
heat of formation (at 25°C) (liq): -94 kcal/mol
heat of formation (at 25°C) (gas): -81 kcal/mol } (114)

Flammability:
Rapid oxidation in air; will ignite spontaneously if spread over a large area (101).

(METHYL Sily) AMINO BORANE

<u>Mol. Wt.:</u> 86.81	<u>Formula:</u> $(\text{B}_2\text{H}_5)\text{N}(\text{CH}_3)(\text{SiH}_3)$	<u>B.P.:</u> 51°C (226)
<u>M.P.:</u> -39.0°C (226)	<u>Characteristics</u> Liquid - colorless (226)	<u>V.P.:</u> 82° (226)

Solubility:
s. organic solvents; d. H_2O , air (226)

Thermodynamic properties
heat of vaporization (at 60°C): 7716 cal/mol (226)

Flammability:
Spontaneously flammable (226).

DIMETHYLAMINOCHLOROBORANE

<u>Mol. Wt.:</u> 105.11	<u>Formula:</u> $(\text{CH}_3)_2\text{NB}_2\text{H}_4\text{Cl}$	
	<u>Characteristics</u> Liquid (103)	$\frac{n_D^{20}}{d_4^{20}}$ 6.5 (103)
		$\frac{n_D^{20}}{d_4^{20}}$ 18 (103)

Synthesis
n-methyl derivative of $\text{B}_2\text{H}_7\text{N}$ (29)

Solubility:

s. organic solvent; d. H₂O, air (103)

Flammability:

Spontaneously flammable (29)

1, 1, 2 - TRIMETHYL DIBORANE

Mol. Wt.:

69.75

Formulas

B₂H₃(CH₃)₃

((CH₃)₂BHBH₂(CH₃))

B.P.:

45.5°C (79)

M.P.:

-123°C (79)

Characteristics

Liquid - colorless (79)

Solubility:

s. organic solvent; d. H₂O, air (103)

Thermodynamic properties

heat of combustion: 24,000 Btu/lb (202)

heat of vaporization: 7.0 kcal/mol (103)

Flammability:

Spontaneously flammable (202).

TETRAMETHYL DIBORANE

Formulas

H(CH₃)₂BB(CH₃)₂H (See pages 181-182)

TRIETHYL DIBORANE

Mol. Wt.:

111.82

Formulas

(C₂H₅)₃B₂H₃

Characteristics

Liquid - colorless (226)

V.P.:

40° (226)

Solubility:

s. organic solvents (226)

Flammability:

Spontaneously flammable (226)

N-METHYL N, N-BIS(DIETHYLBORINIC)IMIDE

Mol. Wt.:

166.92

Formulas

((C₂H₅)₂B)₂NCH₃

Characteristics

Liquid (209)

B.P.:

4612.6 (209)

Synthesis:

Diethylboron chloride reacts with 1 mole monomethylamine using triethylamine in excess as an HCl acceptor (205); $(C_2H_5)_2BCl + CH_3NH_2 + (C_2H_5)_3N \rightarrow ((C_2H_5)_2B)_2NCH_3 + (C_2H_5)_3NHCl$ (209)

Flammability:

Spontaneously flammable (205).

TETRABUTYL DIBORANYL OXYETHANE

Mol. Wt.:

310.14

Formulas:

$(C_4H_9)_2BOCH_2CH_2OB(C_4H_9)_2$

d./sp. gr.:

.8266²⁵ (226)

Characteristics:

Liquid - colorless (226)

V.P.:

2144
10168-169
1133-134 } (226)

n_D^{27}

D_4 (226)

1.4343

n_D^{25}

D_4 (226)

1.4323

Flammability:

Spontaneously flammable (226).

TRICHLOROTRIMETHYLBORAZOLE

Mol. Wt.:

225.96

Formulas:

$B_3N_3Cl_3(CH_3)_3$

Synonyms:

NN'N"-Trimethyltrichlorocyl-
triborazine

M.P.:

150°C (210)

Characteristics:

Crystal - colorless (210)

Synthesis:

Reaction of methylamine-boron trichloride complex with triethylamine in toluene gives about 50% trichlorotrimethylborazole (210).

Unique conditions, reaction products:

Reacts violently with water (not pyrophoric) (210).

HEF-2 (ALKYLATED PENTABORANE)

Mol. Wt.:

91.12

Formulas:

$C_2H_5B_5H_8$

Synonyms:

Ethyl pentaborane

Toxicity:

Highly toxic on inhalation, ingestion, and skin or eye contact (147).

Unique conditions, reaction products

Reacts slowly with H_2O to yield hydrogen; reacts violently with alcohol (149).

Solubility:

s. H_2O ; s. hydrocarbon fuels, halogenation hydrocarbon fuels (may form extremely shock sensitive mixtures) (149)

Flammability:

Spontaneously flammable (149).

DIMETHYL BERYLLIUM

Mol. Wt.:
39.09

Formula:
 $(CH_3)_2Be$

B.P.:
d. $190^\circ C$ (226)

M.P.:
Sublimes $200^\circ C$ (226)

Characteristics:
Needles - white (226)

V.P.:
1408 (226)
30.5158.6

Toxicity:
High (195)

Synthesis:

- (1) $(CH_3)_2Hg + Be \rightarrow (CH_3)_2Be + Hg$ (110)
(2) $Cl_2Be[O(C_2H_5)_2]_2 + 2CH_3MgX \rightarrow (CH_3)_2Be + MgX_2 + MgCl_2$ (110)

Unique conditions, reaction products

Evolves dense white fumes in moist air (110)

Solubility:
s. hot ether (226)

Thermodynamic properties:
heat of sublimation 22 kcal/mol (226)

Military and industrial uses:
Potential high energy propellant (110)

Flammability:
Spontaneously flammable in moist air (110).

DIETHYL BERYLLIUM

Mol. Wt.:
67.14

Formula:
 $Be(C_2H_5)_2$

B.P.:
(extrapolated) $194^\circ C$ (226)

M.P.:
 $-13^\circ C$ to $-11^\circ C$ (226)

Characteristics:
Liquid - colorless (226)

V.P.:
d. 493-95 (226)

Solubility:

s. organic solvents (226)

Flammability:

Spontaneously flammable (27).

DIISOPROPYLBERYLLIUM

Mol. Wt.:

95.19

Formula:

$\text{Be}(\text{C}_3\text{H}_7)_2$

M.P.:

-9.5°C (103)

Characteristics:

Liquid - colorless (103)

B.P.:

d. 60°C;

(extrapolated) 280°C (103)

Unique conditions, reaction products:

Fumes on exposure to air but does not catch fire, explosive reaction with H_2O (42).

Solubility:

d. air, H_2O ; s. organic solvents (103).

BISMUTH ETHYL CHLORIDE

Mol. Wt.:

274.5

Formula:

$\text{BiC}_2\text{H}_5\text{Cl}$

Characteristics:

Powder (195)

Flammability:

Spontaneously flammable (195).

TRIMETHYL BISMUTH

Mol. Wt.:

254.10

Formula:

$\text{Bi}(\text{CH}_3)_3$

Synonyms:

Trimethylbismuthine

d./sp. gr.:

2.30018 (195)

Characteristics:

Liquid - colorless (195)

B.P.:

110°C (195)

Toxicity:

(1) high (causes narcolepsy and CNS depression); prolonged exposure causes encephalopathy similar to organic lead compounds (195).

Unique conditions, reaction products:

Reactions of methyl magnesium iodide and bismuth chloride (38).

Thermodynamic properties:

heat of formation (liq) +37.5 kcal/mol

heat of formation (gas) +45.8 kcal/mol

heat of vaporization 996.0 ± 1.7 kcal/mol

(114)

Flammability:

Spontaneously flammable (39).

DIETHYL BISMUTH CHLORIDE

Mol. Wt.:

302.47

Formula:

$(C_2H_5)_2BiCl$

Synthesis:

From ethylation of bismuth chloride with tetraethyl lead (39).

Flammability:

Spontaneously flammable (39).

TRIVINYLBISMUTH

Mol. Wt.:

290.14

Formula:

$(CH_2=CH)_3Bi$

B.P.:

158.1722 (242)

Solubility:

s. organic solvents; i. H_2O (242)

Flammability:

Spontaneously flammable (242).

TRIETHYLBISMUTH

Mol. Wt.:

254.09

Formula:

$Bi(C_2H_5)_3$

M.P.:

107°C (52)

Characteristics:

Liquid (79)

V.P.:

(experimental) 79107 (103)

d./sp. gr.:

2.30018 (79)

B.P.:

110°C (79)

Solubility:

s. alcohol, ether; i. H_2O (79)

Thermodynamic properties:

heat of vaporization: 1185.8 ± 2.1 kcal/mol

heat of formation (liq) 40.1 kcal/mol

heat of formation (gas) 51.1 kcal/mol

} (114)

Flammability:

Spontaneously flammable (52).

DIMETHYL CADMIUM

<u>Mol. Wt.:</u> 142.5	<u>Formula:</u> (CH ₃) ₂ Cd	
<u>M.P.:</u> -2.5°C (226)	<u>Characteristics:</u> Liquid - colorless (226)	<u>B.P.:</u> 105.5°C (226)
<u>d./sp. gr.:</u> 1.9846 ^{17.9} (226)	<u>n_D¹⁸:</u> 1.5849 (226)	<u>Atomic refraction:</u> 12.61 (226)

Solubility:

d. H₂O; s. organic solvents (226)

Thermodynamic properties

heat of combustion: 3330 ± 20 cal/g (114)

heat of fusion: 9153 cal/mol at 18°C (226)

enthalpy of combustion: 475.7 ± 2.7 kcal/mol (114)

enthalpy of formation (liq) 18.9 kcal/mol; (gas) 27.8 kcal/mol (114)

Flammability:

Spontaneously flammable (226).

DIETHYL CADMIUM

<u>Mol. Wt.:</u> 170.5	<u>Formula:</u> (C ₂ H ₅) ₂ Cd	
<u>M.P.:</u> -21°C (79)	<u>Characteristics:</u> Liquid - oil (79)	<u>V.P.:</u> 19.564 (103)
<u>d./sp. gr.:</u> 1.6562 (79)	<u>B.P.:</u> 64°C (79)	<u>n_D¹⁸:</u> 1.5680 (103)

Synthesis



Unique conditions, reaction products

Fumes explosively in air, white and then brown clouds appear with detonation (80).

Solubility:

d. H₂O (79); s. organic solvents (103)

Thermodynamic properties

heat of combustion: 4681 ± 5 cal/g

enthalpy of combustion: 800.0 ± .8 kcal/mol

enthalpy of formation (liq) 21.6; (gas) 31.0 kcal/mol

} (114)

Military and industrial uses

TEL production; synthesis of ketones from acid chlorides (190).

COBALTOUS RESINATE

Mol. Wt.:
1368.81 (195)

Formula:
 $\text{Co}(\text{C}_{44}\text{H}_{62}\text{O}_4)_2$

Synonyms:
Cobalt abietate

Characteristics:
powder - red brown (195)

Synthesis:

- (1) (crude) free resin with a cobaltous compound
- (2) mix sodium resinate and a cobalt salt in an aqueous solution (214)

Solubility:
1. H_2O (195)

Military and industrial uses:
Drier in protective coatings (214)

Flammability:
Spontaneously flammable (195).

METHYL COPPER

Mol. Wt.:
78.58

Formula:
 CH_3Cu

Characteristics:
Gas (226)

Synthesis:

Mix methyl lithium and cuprous iodide at -15°C . yellow solid separates which decomposes in boiling ether to yield a formation of metallic copper, methane, and ethane appearing to be methyl copper (40).

Solubility:
1. ether (226)

Flammability:
Explodes violently when allowed to dry in air (40).

TRIMETHYL GALLIUM

Mol. Wt.:
114.82

Formula:
 $\text{Ga}(\text{CH}_3)_3$

B.P.:
 55.7°C (226)

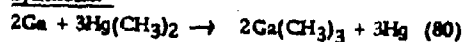
M.P.:
 -15.8°C (226)

Characteristics:
Liquid - colorless (226)

V.P.:
 64.50 (226)

d./sp. gr.:
 $1.131 \pm .00415$ (120)

Synthesis



Solubility

d. H_2O ; s. ether, ammonia (226).

Thermodynamic properties

heat of formation 17.6 kcal/mol (120)

mean heat of combustion $\text{Ga}(\text{CH}_3)_3 (\text{liq}) + \text{CO}_2 \rightarrow \text{Ga}_2\text{O}_3 (\text{crystal}) + 3\text{CO}_2 + 4\frac{1}{2}\text{H}_2\text{O} (\text{liq})$:
6089.3 cal/g (with mean deviation of .24% or 701.0 kcal/mol at 25°C and constant pressure, statistical uncertainty is ± 1.7 kcal/mol) (120).

Flammability

Spontaneously flammable (226).

TRIETHYL GALLIUM

Mol. Wt.:

156.91

Formulas:

$\text{Ga}(\text{C}_2\text{H}_5)_3$

M.P.:

-82.3°C (52)

Characteristics

Liquid - colorless (79)

d./sp. gr.:

1.0576³⁰ (79)

B.P.:

142.6°C (52)

Solubility:

d. cold H_2O ; s. ether (79)

Flammability:

Ignites in air with purple flame and brown smoke (52).

TETRAMETHYL DICALLINE

Mol. Wt.:

199.58

Formulas

$(\text{CH}_3)_2\text{GaGa}(\text{CH}_3)_2$

B.P.:

172°C (extrapolated) (226)

Characteristics

Liquid - colorless (226)

V.P.:

.50
500130 (with d.) (226)

Flammability:

Spontaneously flammable (226).

TRIMETHYL INDIUM

Mol. Wt.:

159.93

Formulas

$\text{In}(\text{CH}_3)_3$

Synonyms

Indium methylate

M.P.:
88.4°C (226)

Characteristics
Crystal (226)

d./sp. gr.:
1.568¹⁰ (226)

B.P.:
135.8°C (226)

V.P.:
7.2³⁰
72⁷⁰ (226)

Solubility:

s. organic polymers; d. H₂O, air (226)

TRIETHYL INDEUM

Mol. Wt.:
202.40

Formulas
(C₂H₅)₃In

M.P.:
-32°C (226)

Characteristics
Liquid - colorless (226)

d./sp. gr.:
1.538²⁰ (226)

B.P.:
144°C (226)

Solubility:

d. H₂O, air; s. organic solvents (226)

Flammability:

Spontaneously flammable in air (226).

TRIPROPYL INDEUM

Mol. Wt.:
244.10

Formulas
(C₃H₇)₃In

M.P.:
-51°C (226)

Characteristics
Liquid - colorless (226)

d./sp. gr.:
1.501²⁰ (226)

B.P.:
178°C (226)

Solubility:

s. organic solvents; d. H₂O, air (226)

Flammability:

Spontaneously flammable (226).

POTASSIUM NITROMETHANE

Mol. Wt.:
99.20

Formulas
KCH₂NO₂

Unique conditions, reaction products

Na or K salts of nitromethane exploded when dry salt was moistened with a little H₂O (143).

TETRAACETENYL NICKEL TETRAPOTASSIUM

Mol. Wt.:

276.13 (103)

Formula:

K₄[Ni(C≡CH)₄]

Characteristics

Red (103)

Flammability:

Spontaneously flammable (103).

METHYL LITHIUM

Mol. Wt.:

21.96

Formula:

CH₃Li

Characteristics

Solid (226)

Synthesis

React lithium metal and methyl chloride in anhydrous ether or dimethyl mercury with ethyl lithium (pure product) $2\text{LiC}_2\text{H}_5 + \text{Hg}(\text{CH}_3)_2 \rightarrow 2\text{LiCH}_3 + \text{Hg}(\text{C}_2\text{H}_5)_2$ (184).

Flammability:

Spontaneously flammable (226).

ETHYL LITHIUM

Mol. Wt.:

36.00

Formula:

LiC₂H₅

Synonyms:

Lithium ethyl

M.P.:

95°C (103)

Characteristics

Tablets - colorless (103)

V.P.:

.00045⁷⁰ (103)

B.P.:

sublimes (103)

Solubility:

s. organic solvents (103)

Flammability:

Spontaneously flammable (50).

N-PROPYL LITHIUM

Mol. Wt.:
50.04

Formula:
 LiC_3H_7

Characteristics
Liquid - colorless (103)

V.P.:
.000550 (103)

Flammability:

Spontaneously flammable (50).

BUTYL LITHIUM

Mol. Wt.:
64.05

Formula:
 LiC_4H_9

M.P.:
sublimes at $80^\circ\text{--}100^\circ\text{C}$
(in vacuo)

Characteristics
Liquid - colorless (103)

V.P.:
.0004560
.00170 (103)

d./sp. gr.:
.68 - .70 (190)

B.P.:
 130°C (79)

Toxicity:

Caustic; burns with skin contact (81).

Synthesis:

Reaction of finely dispersed lithium metal with butyl chloride (138).

Solubility:

s. organic solution (103)

Thermodynamic properties

heat of sublimation: 33 kcal/mol (103)

dipole moment: .970 (103)

Military and industrial uses

Used as stereo-regulator for polymerizations to complex organic compounds; as a catalyst for polyisoprene rubber; and as a metalating agent (138).

Flammability:

Can spontaneously ignite in air if: 20% or more LiC_4H_9 and relative humidity over 70%; concentrations above 25% generally pyrophoric under any range of humidity (138).

LITHIUM TETRAMETHYL BORATE

Mol. Wt.:
38.77

Formula:
 $\text{Li}(\text{CH}_3)_4\text{B}$

Synthesis

React methyl lithium and trimethylborane in ethyl ether (48).

Unique conditions, reaction products

Stable in very dry air (48).

Solubility:

s. ether (48).

Flammability:

May ignite spontaneously in moist air (48).

PHENYL LITHIUM

Mol. Wt.:

84.00

Formula:

C_6H_5Li

Synthesis

(1) $(C_6H_5)_4Pb + 4C_2H_5Li \rightarrow (C_4H_9)_4Pb + 4C_6H_5Li$ (184)

(2) $(C_6H_5)_3Sb + 3C_2H_5Li \rightarrow 3C_6H_5Li + (C_2H_5)_3Sb$ (184)

Flammability:

Spontaneously flammable (50).

METHYLENE DILITHIUM

Mol. Wt.:

27.91

Formula:

$LiCH_2Li$

Characteristics:

Solid - brown (226)

Solubility:

d. H_2O , air; i. alcohol (226)

Flammability:

Spontaneously flammable in air (226).

METHYLENE MAGNESIUM

Mol. Wt.:

38.35

Formula:

$MgCH_2$

Characteristics:

Solid - rust colored,
amorphous (226)

Synthesis



Solubility:

d. H_2O , air; i. organic solvents (226)

Flammability:

Spontaneously flammable (34).

DIMETHYL MAGNESIUM

Mol. Wt.:

54.50

Formula:

$\text{Mg}(\text{CH}_3)_2$

M.P.:

d. 200°C (226)

Characteristics:

Solid (226)

V.P.:

.2190 (226)

Solubility:

s. ether (226)

Flammability:

Spontaneously flammable (34)

MAGNESIUM DIETHYL

Mol. Wt.:

82.44

Formula:

$\text{Mg}(\text{C}_2\text{H}_5)_2$

M.P.:

0°C (195)

Characteristics:

Liquid (room temperature)
(195)

B.P.:

d. 176°C (103)

Synthesis

Precipitated by action of Mg on $\text{Hg}(\text{C}_2\text{H}_5)_2$ in ether (132).

Unique conditions, reaction products:

Violent reaction with H_2O , steam or oxidizing materials (195); spontaneously flammable in CO_2 (143).

Solubility:

s. ether (132).

Flammability:

Spontaneously flammable in air (195).

DIBUTYL MAGNESIUM

Mol. Wt.:

138.72

Formula:

$(\text{C}_4\text{H}_9)_2\text{Mg}$

M.P.:
d. 200°C (226)

Characteristics
Crystal (226)

Solubility:
s. ether (226)

Flammability:
Spontaneously flammable (226).

MAGNESIUM DIPHENYL

Mol. Wt.:
178.5

Formula:
 $Mg(C_6H_5)_2$

M.P.:
d. 280°C (132)

Characteristics
Crystals - feathery

Synthesis
Action of Mg on $Hg(C_6H_5)_2$ (132)

Unique conditions, reaction products
Violent reaction in H_2O or steam (195).

Flammability:
Spontaneously flammable in moist (not dry) air (195).

DIMETHYL MANGANESE

Mol. Wt.:
84.96

Formula:
 $[(CH_3)_2Mn]_n$

Synthesis
 $MnI_2 + 2CH_3Li \rightarrow [(CH_3)_2Mn]_n$ (245)

Solubility
i. ether; s. excess $CH_3Li \rightarrow Li[Mn(CH_3)_3]$ (245)

Flammability:
Spontaneously flammable (245)

BIS-CYCLOPENTADIENYL MANGANESE

Mol. Wt.:
185.13

Formula:
 $Mn(C_5H_5)_2$

B.P.:
245°C (226)

M.P.:
172° - 173°C (226)

Characteristics
Crystals - amber,
paramagnetic (226)

V.P.:
(10⁻⁴-10⁻⁵)100-130 (226)

Synthesis

React sodium cyclopentadienide with anhydrous manganese dibromide in tetrahydrofuran or glycol dimethyl ether at reflux temperature in the absence of oxygen, followed by the removal of the solvent and sublimation at 130°C and 10-4 mm. 45% yield (184).

Unique conditions, reaction products

Liberates cyclopentadiene and manganese dioxide or its salt on reaction with H₂O, aqueous bases or acids (184).

Solubility

sl. s. CS₂, CCl₄, chloroform (slow reaction); moderately s. benzene, ether, c. dioxane;
very s. pyridine, tetrahydrofluoride (184)

Thermodynamic properties

heat of fusion: 6.3 kcal/mol
specific conductivity: $1.4 \times 10^{-5}(\text{NH}_3)$ (at -33°C) } (226).
heat of vaporization: 12.0 kcal/mol
heat of sublimation: 17.3 kcal/mol

Military and industrial uses

Used in gas plating of heated surfaces in a vacuum (92)

Flammability

Spontaneously flammable (226).

SODIUM NITROMETHANE

Mol. Wt.:

83.3

Formula:

NaCH₂NO₂

Unique conditions, reaction products

Na or K salts of nitromethane exploded when dry salt was moistened with a little H₂O (143).

METHYL SODIUM

Mol. Wt.:

38.00

Formula:

CH₃Na

M.P.:

200°C (226)

Characteristics

Solid (226)

Solubility:

i. organic; d. air, H₂O (226)

Flammability

Spontaneously flammable (226).

SODIUM METHYLATE

<u>Mol. Wt.:</u> 54.03	<u>Formula:</u> <chem>CH3ONa</chem>
<u>d./sp. gr.:</u> 4.6 lbs/gal (132)	<u>Characteristics:</u> Powder - white (132).
<u>Solubility:</u> d. H_2O (132).	
<u>Military and industrial uses:</u> Organic syntheses (132)	

Flammability:
Spontaneously flammable in moist air (143).

SODIUM ACETATE

<u>Mol. Wt.:</u> 82.03	<u>Formula:</u> <chem>CH3C(O)ONa</chem>
<u>M.P.:</u> 324°C (195)	<u>Characteristics:</u> Crystal - white (195)
<u>d./sp. gr.:</u> 1.528 (195)	<u>n_D^{20}:</u> 1.464 (79)
<u>Solubility:</u> sl. s. alcohol; s. H_2O , organic polymers; i. organic solvents (79)	
<u>Military and industrial uses:</u> Buffer in photography, mordant in dyeing (132).	

Flammability:
Possible spontaneous flammability in moist air or H_2O (27)

ETHYL SODIUM

<u>Mol. Wt.:</u> 52.06	<u>Formula:</u> <chem>NaC2H5</chem>
<u>M.P.:</u> Decomposes (226)	<u>Characteristics:</u> Crystal - white (226)
<u>Solubility:</u> d. H_2O , alcohol, ether, air; i. organic; s. diethyl zinc (226)	

Flammability

Spontaneously flammable (226)

BENZYL SODIUM
(Solid)

Mol. Wt.:

114.06

Formula:

$C_6H_5 \cdot CH_2 \cdot Na$

M.P.:

Decomposes (184)

Characteristics

Powder - white (152)

Solubility:

s. ether (184)

Flammability:

Spontaneously flammable (50)

METHYL PHOSPHINE

Mol. Wt.:

48.03

Formula:

CH_3PH_2

B.P.:

25°C (226)

Characteristics

Gas - colorless (103)

V.P.:

1.75⁰ (103)

Toxicity:

Highly toxic on inhalation (195).

Unique conditions, reaction products

Forms fairly volatile crystalline salts with HCl and HI (231).

Solubility:

sl. d. H_2O , alcohol; s. ether (103)

Flammability:

Spontaneously flammable (93).

DIMETHYL PHOSPHINE

Mol. Wt.:

62.05

Formula:

$(CH_3)_2PH$

V.P.:

30-47 (226)

d./cp. gr.:

< 1 (195)

Characteristics

Liquid - colorless (226)

B.P.:

25°C (226)

V.d.:

2.14 (195)

Toxicity

High on ingestion and/or inhalation (195)

Solubility

s. organic solvents; d. air (226)

Flammability

Spontaneously flammable in air (195)

TRIMETHYL PHOSPHINE

Mol. Wt.:
76.08

Formula:
 $P(CH_3)_3$

M.P.:
-85.9°C (103)

Characteristics
Liquid - colorless (79)

d./sp. gr.:
<1 (79)

B.P.:
40°-42°C (79)

Toxicity

Vapors of burning are highly toxic (246)

Synthesis

Combines PCl_3 and CH_3MgBr and di-n-butyl ether, then distill phosphine quietly from the mixture in dry N_2 atmosphere following distillation of the ether; use of dry-oxygen-free atmosphere in preparation is essential (246)

Solubility

l. H_2O ; s. ether (79)

Thermodynamic properties

heat of vaporization: 6.92 kcal/mol (103)
heat of combustion: 1004 ± 11 cal/g
enthalpy of combustion: $763.2 \pm$ kcal/mol
enthalpy of formation (liq) -30.1 kcal/mol; (gas) -23.2 kcal/mol } (114)

Flammability

Burns violently in the air (246).

DIETHYL PHOSPHINE

Mol. Wt.:
90.11

Formula:
 $(C_2H_5)_2PH$

B.P.:
85°C (195)

d./sp. gr.:
<1 (195)

Characteristics
Liquid - colorless (103)

V.d.:
3.11 (195)

Toxicity

High on ingestion or inhalation (195)

Solubility:

s. organic solvents (103)

Flammability:

Spontaneously flammable in air (195).

TRIFLUOROMETHYL PHOSPHINE

Mol. Wt.:

102.00 (226)

Formula:

F_3CPH_2

Characteristics:

gas (226)

B.P.:

-25.5°C (226)

Flammability:

Spontaneously flammable (226)

BIS-TRIFLUOROMETHYL CHLOROPHOSPHINE

Mol. Wt.:

204.44

Formula:

$(F_3C)_2PCl$

Characteristics:

Liquid - colorless (103)

B.P.:

21°C (79)

Solubility:

d. H_2O (79), alkaline solvents (103); s. organic polymers (103)

Flammability:

Spontaneously flammable (79).

BIS-TRIFLUOROMETHYL PHOSPHINE

Mol. Wt.:

170.01

Formula:

$(CF_3)_2PH$

Characteristics:

Gas - colorless (226)

B.P.:

1°C (226)

Solubility:

s. organic polymers (226)

Flammability:

Spontaneously flammable (226)

BIS-TRIFLUOROMETHYL CYANOPHOSPHINE

Mol. Wt.:

195.00

Formula:

$(F_3C)_2PCN$

n_D²⁰
1.3248 (79)

Characteristics
Liquid - colorless (79)

B.P.
48°C (79)

Solubility:

s. organic polymers; i. H₂O (103).

Flammability:

Spontaneously flammable (79)

TRIS-TRIFLUOROMETHYL PHOSPHINE

Mol. Wt.:
238.01 (226)

Formula:
(CF₃)₃P

Characteristics
Liquid - colorless (226)

B.P.:
17.3°C (27)

Solubility:

d. H₂O; s. organic polymers (226)

Thermodynamic properties:

heat of vaporization: 5890 cal/mol (226)

Flammability:

Spontaneously flammable (79)

TRIBUTYL PHOSPHINE

Mol. Wt.:
262.32

Formula:
P(C₄H₉)₃

F.P.:
-60° to -65°C (190)

B.P.:
245°C (190)

V.P.:
50/26 (103)

d./sp. gr.:
.810025₄ (190)

n_D²⁵
1.4588 (190)

Ignition temperatures:

flash point: 40°C
fire point: 43°C
autoignition temperature: 260°C } (190)

Solubility:

Almost i. H₂O; miscible with ether, methanol, ethanol and benzene (190)

Military and industrial uses:

Fuel additive; epoxy resin curing catalyst; vinyl and isocyanate polymerization; inorganic intermediate (190)

Flammability

Spontaneously flammable in air (217)

1, 1, 3-TRIETHYL ETHOXY DIPHOSPHINYL OXIDE

Mol. Wt.:

210.20

Formula:

$(C_2H_5)_2PCP(C_2H_5)(OC_2H_5)$

Y.P.:

1591-93 (103)

d./sp. gr.:

1.0004²⁰ (103)

Characteristics

Liquid - colorless (103)

²⁰D₄

1.4868 (103)

Solubility

s. organic; d. H₂O; air (103)

Flammability:

Spontaneously flammable (103)

ANTIMONY TRIMETHYL

Mol. Wt.:

166.86

Formula:

$(CH_3)_3Sb$

Synonyms

Trimethyl stibine

M.P.:

-87.6°C (103)

Characteristics

Liquid (195)

d./sp. gr.:

1.5231⁵ (79)

B.P.:

80.6°C (79)

Unique conditions, reaction products

Reacts vigorously with oxidizing materials (195).

Solubility

sl. s. cold and hot H₂O; s. ether; i. alcohol (79)

Thermodynamic properties

heat of vaporization	7.82 kcal/mol	} (103)
heat of formation	-1.4 kcal/mol	
heat of combustion	698 kcal/mol	
heat of combustion	4172 ± 18 cal/g	} (114)
enthalpy of combustion	693.0 ± 31 kcal/mol	
enthalpy of formation (liq)	-1.4 kcal/mol	

Flammability

Spontaneously flammable in air (195)

TRIMETHYL ANTIMONY SULFATE

Mol. Wt.:

262.85

Formula:

$(CH_3)_3SbSO_4$

Flammability

Spontaneously flammable in air (14).

TRIVINYL STIBINE

Mol. Wt.:

202.90

Formulas

$(CH_2=CH)_3Sb$

Characteristics

Liquid - colorless (103)

B.P.:

149.9722 (103)

Solubility

s. organic solvents (241)

Flammability

Spontaneously flammable (241)

ANTIMONY TRIETHYL

Mol. Wt.:

208.94

Formulas

$Sb(C_2H_5)_3$

Synonyms

Triethyl stibine

M.P.:

< -29°C (79)

Characteristics

Liquid (79)

B.P.:

159.5°C (79)

d./sp. gr.:

1.32416 (79)

n_D^{15}

1.42 (79)

Solubility

l. H_2O ; s. alcohol, ether (79)

Thermodynamic properties

heat of combustion: 5552 ± 6 cal/g

enthalpy of combustion: 1162.6 ± 1.2 kcal/mol

enthalpy of formations (liq) 2.3 kcal/mol; (gas) 13.1 kcal/mol } (114)

Flammability

Spontaneously flammable (195).

TRIETHYL ANTIMONY SULFATE

Mol. Wt.:

304.88

Formulas

$Sb(C_2H_5)_3SO_4$

Flammability

Spontaneously flammable in air (14).

PHENYLDIMETHYL ANTIMONY

Mol. Wt.:
228.93

Formula:
 $\text{C}_6\text{H}_5\text{Sb}(\text{CH}_3)_2$

Characteristics
Liquid - colorless oil (79)

B.P.:
112-15-18 (79)

Flammability:
Fumes in air (79)

TRIPROPYL ANTIMONY

Mol. Wt.:
250.85

Formula:
 $\text{Sb}(\text{C}_3\text{H}_7)_3$

M.P.:
80-81°C (50)

Flammability:
Ignites or carbonizes on filter paper (52).

TETRAMETHYL DISTIBINE

Mol. Wt.:
303.56

Formula:
 $(\text{CH}_3)_2\text{SbSb}(\text{CH}_3)_2$

M.P.:
175°C (37)

V.P.:
18-100 (37)

Synthesis
Reaction of methyl radicals (from tetramethyl lead by pyrolysis) and an antimony mirror (37).

Flammability:
Spontaneously flammable (37)

BIS-DIMETHYLSTIBINE OXIDE

Mol. Wt.:
319.56

Formula:
 $[(\text{CH}_3)_2\text{Sb}]_2\text{O}$

Synthesis
Hydrolysis $(\text{CH}_3)_2\text{SbBr}$ with alkali (36)

Flammability:
Spontaneously flammable (36)

METHYL TRICHLORO SILANE

Mol. Wt.:
149.50

Formula:
CH3SiCl3

M.P.:
-77.8°C (103)

Characteristics
Liquid - colorless (acid
odor) (103)

V.P.:
10-27 (103)
60³

d./sp. gr.:
1.273²⁵
25 (103)

B.P.:
66.4°C (103)

Viscosity:
.37 cs (at 25°C) (103)

n_D²⁵
D₄ (103)
1.415

Unique conditions, reaction products

Evolves white fumes with moist air; violent reaction with H₂O yields heat and white acid fumes (54)

Ignition temperatures

flash point: 45°F
autoignition temperatures: 410°C } (103)

Solubility:

s. organic solvents; d. H₂O, alcohol (103)

Thermodynamic properties

heat of vaporization: 84.9 Btu/lb
surface tension: 20.3 dynes/cm
specific heat: .22
coefficient of expansion: .0013 } (103)

VINYL TRICHLORO SILANE

Mol. Wt.:
161.51

Formula:
SiC2H3Cl3

M.P.:
-95°C

Characteristics
Liquid - colorless
(acid odor) (103)

V.P.:
10-11
60²³
100³⁴ } (103)

d./sp. gr.:
1.264²⁵
1.265²⁰ (103)

B.P.:
91°-93°C (103)

n_D²⁵
D₄ (103)
1.432

Viscosity:
.50 cs (at 25°C) (103)

n_D²⁰
D₄ (103)
1.4365

Unique conditions, reaction products

Evolves white fumes with moist air; violent reaction with H_2O (yields heat and white acrid fumes) (54).

Ignition temperature:

flash point: $70^{\circ}F$ (103)

Solubility:

s. organic solvents; d. H_2O , alcohol (103)

Thermodynamic properties

coefficient of expansion .0016/ $^{\circ}C$
heat of vaporizations 88 Btu/lb
specific heat: .20

} (103)

ETHYL TRICHLOROSILANE

Mol. Wt.:

163.51

Formula:

$C_2H_5SiCl_3$

M. P.:

$-105.6^{\circ}C$ (184)

Characteristics

Liquid - colorless
(acrid odor) (103)

Viscosity:

.48 cs (at $25^{\circ}C$) (103)

d./sp. gr.:

1.238^{20}_4 (103)

B. P.:

$97-103^{760}$ (103)

n^{20}_D

$\frac{D_4}{1.4257}$ (103)

Unique conditions, reaction products

Evolves white fumes with moist air; violent reaction with H_2O (yields heat and white acrid fumes) (54).

Ignition temperature:

flash point: $80^{\circ}F$ (103)

Solubility:

d. H_2O , alcohol (103)

Thermodynamic properties

heat of vaporizations 99 Btu/lb
coefficient of expansion .0015/ $^{\circ}C$ (103)

DIMETHYL DICHLOROSILANE

Mol. Wt.:

129.07

Formula:

$(CH_3)_2SiCl_2$

M. P.:

$-76^{\circ}C$ (103)

Characteristics

Liquid - colorless
(acrid odor) (103)

V. P.:

10-25
606.5 (103)

d./sp. gr.:
1.070²⁵₂₅ (103)

B.P.:
73.5°C (103)

Viscosity:
.47 cs (at 25°C) (103)

n_D²⁵
D₄ (103)
1.405

Unique conditions, reaction products

Evolves white fumes with moist air; violent reaction with H₂O (yields heat and white acrid fumes) (54).

Ignition temperatures:

autoignition temperatures: 410°C (103)
flash point: 15°F

Solubility:

s. organic solvents; d. H₂O, alcohol (103).

Thermodynamic properties

heat of vaporization: 99.4 Btu/lb
surface tension: 20.1 dynes/cm
coefficient of expansion: .0013/°C } (103)

TRIMETHYL CHLOROSILANE

Mol. Wt.:
108.65

Formula:
(CH₃)₃SiCl

M.P.:
-57.7°C (103)

Characteristics:
Liquid - colorless
(acrid odor) (103)

V.P.:
10-34
60-4
100⁶
40039.4 } (103)

d./sp. gr.:
.854²⁵₂₅ (103)
.846²⁵₄

B.P.:
57.9°C (103)

n_D²⁰
D₄ (103)
1.3884

Viscosity:
.47 cs (at 25°C) (103)

Surface tension:
9.5 dynes/cm (at 20°C) (103)

Unique conditions, reactions:

Evolves white fumes with moist air; violent reaction with H₂O (yields heat and white acrid fumes) (54)

Ignition temperatures:

flash point: -16°F (103)
autoignition temperatures: 400°F

Solubility:

s. organic solvents (103)

PROPYL SILANE

Mol. Wt.:
74.20

Formula:
 $\text{Si}(\text{C}_3\text{H}_7)_3$

d./sp. gr.:
.6434²⁰₄ (103)

Characteristics
Liquid - colorless (103)

n_D²⁰
1.3759 (103)

B.P.:
23°C (103)

Solubility:

s. organic solvents; i. H_2O (103)

Thermodynamic properties:

heat of combustion: 19,000 Btu/lb (202)

Flammability:

Spontaneously flammable (103).

DIETHYL DICHLOROSILANE

Mol. Wt.:
157.13

Formula:
 $(\text{C}_2\text{H}_5)_2\text{SiCl}_2$

M.P.:
-96.5°C (184)

Characteristics
Liquid - colorless (103)

V.P.:
100⁶⁹₁₀₂₁ (103)

d./sp. gr.:
1.0504²⁰₄ (79)

B.P.:
129°C (79)

n_D²⁰
1.4809 (79)

Unique conditions, reaction products:

Fumes strongly in moist air, so intense that leaky containers appear to be on fire (54).

Solubility:

d. cold H_2O ; s. ether (79)

TETRAMETHYL SILANE

Mol. Wt.:
88.23

Formula:
 $(\text{CH}_3)_4\text{Si}$

M.P.:
 α -101.7°C (226)
 β -99.5°C

Characteristics
Liquid - colorless (226)

n_D²⁰
1.3582 (226)

B.P.:
26.2°C (226)

d./sp. gr.:
.6688²⁰₄ (226)
.6480²⁰₄

Solubility:s. organic solvents; i. H₂O (226)Thermodynamic properties

heat of vaporization: 6.25 kcal/mol (at 26.2°C)
 heat of formations (liq) -69 kcal/mol; (gas) -63 kcal/mol
 heat of combustions -920 kcal/mol

} (226)

Flammability:

Spontaneously flammable (226).

AMYL TRICHLOROSILANE

Mol. Wt.:

205.60

FormulasSiC₅H₁₁Cl₃d./sp. gr.:1.137²⁵₂₅ (103)Characteristics

Liquid - colorless (103)

V.P.:120¹⁰⁷ (103)n_D²⁵

1.4415 (103)

B.P.:

166°-169°C (103)

Viscosity

1.10 cs (at 25°C) (103)

n_D²⁰

1.445 (103)

Unique conditions, reaction products

Fumes strongly in moist air (54).

Ignition temperatures

flash point: 135°F (103)

Solubility:s. organic solvents; d. H₂O (103)Thermodynamic properties

specific heat: .35 (103)

coefficient of expansion .0014/°C

BENZYL SILANE

Mol. Wt.:

122.25

FormulasC₆H₅·CH₂SiH₃n_D²⁵

1.505 (103)

Characteristics

Liquid - colorless (103)

V.P.:

3053 (103)

Solubility

1. H_2O ; s. organic solvents (103)

Thermodynamic properties

heat of combustion: 19,000 Btu/lb (202)

Flammability

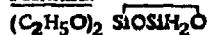
Spontaneously flammable (202)

DETHOXY SILOXENE

Mol. Wt.:

226.43

Formula:



Solubility

d. H_2O (103)

Flammability

Spontaneously flammable (103)

BIS(ETHYLAMINO) SILOXENE

Mol. Wt.:

280.57

Formula:



Characteristics

Solid - orange (226)

Solubility

d. H_2O , air (226)

Flammability

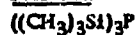
Spontaneously flammable (226).

TRISTRIMETHYL SILYL PHOSPHINE

Mol. Wt.:

250.33

Formula:



Characteristics

Liquid (157)

B.P.:

253°C (157)

Synthesis

React $NaPH_2$ and $(CH_3)_3SiCl$ in an ether solvent at room temperature and distill in a spinning band column (157).

Flammability

Spontaneously flammable (157).

TRIETHYL TELLUREUM

Mol. Wt.:
214.67

Formula:
 $\text{Te}(\text{C}_2\text{H}_5)_3$

M.P.:
138°C (52)

Characteristics:
Liquid - reddish yellow (52)

Flammability:
Spontaneously flammable in air (52).

ISOBUTYL TITANIUM TRICHLORIDE

Mol. Wt.:
211.29

Formula:
 $\text{i-C}_4\text{H}_9\text{TiCl}_3$

Characteristics:
Solid (128)

Flammability:
Nearly pyrophoric (128).

TRIMETHYL THALLIUM

Mol. Wt.:
249.38

Formula:
 $(\text{CH}_3)_3\text{Tl}$

M.P.:
38.5°C (226)

Characteristics:
Needles - colorless (226)

V.P.:
520 (226).

B.P.:
147°C (extrapolated) (226).

Solubility:
d. light, H_2O ; s. organic solvent (226).

Flammability:
Spontaneously flammable (226).

PHENYL DICYCLOPENTADIENYL VANADIUM

Mol. Wt.:
258.11

Formula:
 $(\text{C}_5\text{H}_5)_2\text{VC}_6\text{H}_5$

Flammability:
Spontaneously flammable in air (243)

TRITERTIARY TUNGSTEN-TRIS(PHENYL LITHIUM)-TRIS(DIETHYL ETHER)

Mol. Wt.:
875.81

Formulas
 $(C_6H_5)_3W \cdot 3LiC_6H_5 \cdot 3(C_2H_5)_2O$

Characteristics
Violet (226)

Solubility:

s. organic solvent; d. H_2O , alcohol (226).

Flammability:

Spontaneously flammable (226).

ZINC DIMETHYL

Mol. Wt.:
95.45

Formulas
 $Zn(CH_3)_2$

M.P.:
-42°C (224)

Characteristics
Liquid - colorless (226)

V.P.:
124° (226).

d./sp. gr.:
1.386¹⁰ (226)

B.P.:
46°C (226)

Thermodynamic properties

heat of combustion: 5050 ± 15 cal/g
enthalpy of combustion: 433.2 ± 1.4 kcal/mol
enthalpy of formation: (liq) 6.5; (gas) 13.3 kcal/mol } (1.4)

Flammability:

Spontaneously flammable in air (226).

DIVINYLYL-ZINC

Mol. Wt.:
119.42

Formulas
 $(CH_2=CH)_2Zn$

B.P.:
32°C (241)

Unique conditions, reaction products

Yield ethylene on contact with H_2O (241).

Synthesis

$ZnCl_2 + 2CH_2=CHMgBr \xrightarrow{(CH_3)_2CO} (CH_2=CH)_2Zn + 2MgBrCl$ (241)

Flammability:

Spontaneously flammable in air (241).

ZINC ISOBUTYL

Mol. Wt.:
179.6

Formula:
 $\text{I-CH}_3(\text{CH}_2)_3\text{Zn}$

Unique conditions, reaction products:
Reacts with H_2O to yield ethane (27).

Flammability:
Spontaneously flammable (27).

DIETHYL ZINC

Mol. Wt.:
123.50

Formula:
 $\text{Zn}(\text{C}_2\text{H}_5)_2$

M. P.:
-30°C (226)

Characteristics:
Liquid - colorless (226)

V. P.:
27.30 (226)

d./sp. gr.:
1.18218 (226)

B. P.:
117.6°C (226)

n_D
1.4936 (226)

Toxicity:
When burning, yields zinc oxide fumes (threshold value 5 mg/m^3) (142).

Synthesis:
 $\text{Zn} + \text{C}_2\text{H}_5\text{I} \rightarrow \text{C}_2\text{H}_5\text{ZnI} (2) \rightarrow \text{Zn}(\text{C}_2\text{H}_5)_2 + \text{ZnI}_2 (80)$

Unique conditions, reaction products:
Extremely violent decomposition in H_2O to yields $\text{Zn}(\text{OH})_2 + \text{C}_2\text{H}_5 (80)$.

Solubility:
d. H_2O , alcohol; s. organic solvents (226)

Handling:
Ship in sealed tubes or steel cylinders, protect from physical damage, keep cool and dry (142).

Thermodynamic properties:
heat of formation: (liq) 5.2 kcal/mol; (gas) 142 kcal/mol
heat of combustion: $6481 \pm 4 \text{ cal/g}$ } (114)

Military and industrial uses:
Igniter for capsule firing flame thrower (99).

Flammability:
Spontaneously flammable in air (226).

ZINC ISOAMYL

Mol. Wt.:
136.43

Formulas
 $\text{I-CH}_3(\text{CH}_2)_4\text{Zn}$

Characteristics
Liquid (27)

Unique conditions, reaction products
Reacts with H_2O to yield C_2H_6 (27)

Flammability:
Spontaneously flammable (27).

DI-n-PROPYL ZINC

Mol. Wt.:
151.55

Formulas
 $\text{Zn}(\text{C}_3\text{H}_7)_2$

d./sp. gr.:
 1.1034^{20}_4 (226)

Characteristics
Liquid (226)

V.P.:
 10^{48} (226)

B.P.:
 160°C (226)

$n^{18.6}_{\text{D}}$
1.4845 (226)

Unique conditions, reaction products
Reacts with H_2O to yield C_2H_6 (27)

Solubility:
d. H_2O ; s. organic solvents (226).

Thermodynamic properties
heat of formation: (llq) -3.9 kcal/mol; (gas) -13.6 kcal/mol
enthalpy of combustions 1113.3 ± 5.6 kcal/mol } (114)

Flammability:
Spontaneously flammable (226).

TETRAMETHYL DIBORANE

Mol. Wt.:
83.79

Formulas
 $(\text{H}(\text{CH}_3)_2\text{BB}(\text{CH}_3)_2\text{H})$

M.P.:
 -73°C (103)

Characteristics
Liquid (103)

B.P.:
 69°C (103)

Solubility:
s. organic solvent; d. H_2O , air (103).

Thermodynamic properties

heat of combustion: 24,000 Btu/lb (202)

heat of vaporization: 7.3 kcal/mol (103)

Flammability:

Spontaneously flammable (200)

(b) HALIDES

DI-CHLOROACETYLENE

<u>Mol. Wt.:</u> 94.93	<u>Formula:</u> $\text{ClC}\equiv\text{CCl}$	<u>Synonyms:</u> Dichloroethyne
<u>M.P.:</u> -66°C (79)	<u>Characteristics:</u> Gas (123)	<u>B.P.:</u> Explodes (79)

Synthesis:

Trichloroethylene with caustic soda decomposes to form di- or trichloroacetylene gas (123).

Solubility:

s. alcohol, ether (79)

Flammability:

Ignites or explodes on contact with air (123).

HEXACHLOROETHANE MIXTURE

<u>Mol. Wt.:</u> 236.76	<u>Formula:</u> CCl_3CCl_3	<u>Synonyms:</u> Perchloroethane Carbon hexachloride Carbon trichloride Smoke powder
<u>M.P.:</u> 186.6°C (sublimes) (132)	<u>Characteristics:</u> Solid - rhombic, triclinic or cubic crystals, colorless, camphor-like odor (132)	<u>V.P.:</u> 132.7 (195)
<u>d./sp. gr.:</u> 2.091 (132)		

Toxicity:

Moderately irritating to skin, mucous membranes and liver. Narcotic in high concentrations (132).

Solubility:

i. H_2O ; s. alcohol, benzene, chloroform, ether, oils (132)

Military and industrial uses:

Solvent, in explosives, camphor substitute in celluloid rubber vulcanizing accelerator (132).

Flammability:

Moisture hazardous, ignites with water (27).

BROMOETHYNE

<u>Mol. Wt.:</u> 104.9	<u>Formula:</u> $\text{HC}\equiv\text{CBr}$	<u>Synonyms:</u> Bromoacetylene Bromoacetylene Ethyneyl chloride
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<u>d./sp. gr.:</u> .0047 (79)	<u>Characteristics</u> Gas (79)	<u>V.d.:</u> 4.684 g/cm ³ (195)
	<u>B.P.:</u> 4°C (79) -2°C (195)	

Solubility:

s. ether, dilute HNO₃, dilute HCl (79)

Flammability:

Spontaneously flammable in air (195)

CHLOROACETYLENE

<u>Mol. Wt.:</u> 60.48	<u>Formulas</u> HCl CCl	<u>Synonyms</u> Chloroethyne Ethanoyl chloride Acetylene chloride
<u>M.P.:</u> -126°C (79)	<u>Characteristics</u> Gas (195)	
<u>d./sp. gr.:</u> .002760 (195)	<u>B.P.:</u> -32°C (79)	

Toxicity:

Unknown (195).

Synthesis:

Can be formed from NaOH and trichloroethylene (123).

Unique conditions, reaction products:

Aqueous solution generates O₃ and glows in the dark (46).

Solubility:

d. H₂O; s. alcohol (79)

Flammability:

Unstable, spontaneously flammable (123).

ACETYL BROMIDE

<u>Mol. Wt.:</u> 122.95	<u>Formulas</u> CH ₃ COBr	<u>Synonyms</u> Ethanoyl bromide Acetic acid bromide
<u>M.P.:</u> -96°C (79)	<u>Characteristics</u> Liquid - colorless fuming (yellow in air) (195)	<u>B.P.:</u> 76.7°C (79)

<u>d./sp. gr.: 1.66316 (79)</u>	<u>$\frac{n_D^{16}}{D_4}$ 1.4538 (79)</u>
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Toxicity:

High (acute local) as irritant, on ingestion and on inhalation (195).

Synthesis:

Interaction of CH_3COOH and PBr_5 (190).

Unique conditions, reaction products:

Violent decomposition with moisture (195).

Solubility:

d. H_2O , alcohol; s. ether, benzene, chloroform (79)

Military and industrial uses:

Organic synthesis and manufacture of dyes (190).

ACETYL CHLORIDE

<u>Mol. Wt.:</u> 78.50	<u>Formulas:</u> CH_3COCl	<u>Synonyms:</u> Ethano,1 chloride Acetic acid chloride
<u>M.P.:</u> -112°C (79)	<u>Characteristics:</u> Liquid - colorless, fuming (79)	<u>V.d.:</u> 2.7 (195)
<u>d./sp. gr.:</u> 1.103921 (79)	<u>B.P.:</u> 51°-52°C (79)	<u>$\frac{n_D^{20}}{D_4}$</u> (79) 1.3898

Toxicity:

High as irritant, on ingestion, and inhalation; when heated emits highly toxic fumes of phosgene (195).

Synthesis:

$\text{CH}_3\text{COOH} + \text{PCl}_3 \rightarrow \text{C}_2\text{H}_3\text{ClO} + \text{HCl} \uparrow$ (190)
(distill)

Unique conditions, reaction products:

Reacts violently on contact with H_2O or alcohol (190).

Solubility:

s. ether, acetone, acetic acid (190)

Handling:

Keep from water (132).

Military and industrial uses:

Used in organic synthesis (preparation of acetic anhydride, dyes and pharmaceuticals) (190).

BENZOYL CHLORIDE

Mol. Wt.:
140.5 (46)

Formula:
 C_6H_5COCl

M.P.:
-1°C (46)

Characteristics:
Liquid - colorless -
fuming (46)

B.P.:
197°C
194.742 (46)

d./sp. gr.:
1.2187¹⁵/₁₅ (36)

n_D²⁰
1.55369 (46)

Unique conditions, reaction products

Smokes in air (191), gives benzoyl derivatives with alcohols, phenols and amines (46).

Solubility:

s. C_6H_6 , ether (191)

ANISOYL CHLORIDE

Mol. Wt.:
170.5

Formula:
 $CH_3OC_6H_4COCl$

Synonyms:
Anisic acid chloride

M.P.:
22°C (46)

B.P.:
160-164.55 (46)

Toxicity:

High (acute local irritant) on ingestion and on inhalation (195).

Unique conditions, reaction products

Hydrolyz s to HCl with H_2O (195).

Solubility:

l. H_2O ; s. acetone, ethane (195)

Military and industrial uses

Intermediates for dyes and medicines (190).

Flammability:

Spontaneous explosion at room temperature (195).

TRI-CHLOROACETYLENE

Characteristics:
Gas

Synthesis

Trichloroethylene with caustic soda decomposes to form di- or trichloroacetylene gas (123).

Flammability

Ignites or explodes on contact with air (123).

(c) MISCELLANEOUS

MONOMETHYLDRAZINE (MMH)

Mol. Wt.:

42.01

Formula:

CH3NHNH2

M.P.:

-62.5°F (149)

Characteristics

Liquid - clear, water-white, ammoniacal odor (149)

V.P.:

3140°F

1080°F

3120°F

79160°F

(149)

d./sp. gr.:

7.32 (at 68°F) (149)

Viscosity:

.85 (at 68°F) (149)

B.P.:

189.5°F (149)

n_D^{20}

1.59

(149)

Toxicity:

Caustic to skin and eyes, can affect respiratory system, potent central stimulant (tremors and convulsions); no threshold limit value set but it is probably below .5 ppm (149).

Unique conditions, reaction products

Reacts with CO₂ and/or O₂ in air, hypergolic with H₂O₂, N₂O₄, F₂, HNO₃ (149)

Ignition temperature:

Open cup flash point: 61°-63°F; autoignition temperature: 382°F; flammability limit 2.5-92 or 98% (149)

Solubility:

Miscible with H₂O, lower weight alcohols, hydrazines (its derivatives) and amines; s. hydrocarbons (149).

Thermodynamic properties

critical temperature: 562°F

critical pressure: 1180° psia

critical density: 1.42 g/cm³

(149)

Flammability:

"... exposure of MMH in air on a large surface (e.g., rags) may result in spontaneous ignition from heat evolved by oxidation with atmospheric O₂" (149).

PRODUCTS OF NITRATION OF DINITROFLUOROETHANE

Unique conditions, reaction products

Air admitted into vacuum at 60°C explosive reaction (9).

ETHYL NITRITE

<u>Mol. Wt.:</u> 75.07	<u>Formula:</u> $C_2H_5NO_2$	<u>Synonyms:</u> Nitrous ether
<u>d./sp. gr.:</u> .9 (195)	<u>B.P.:</u> 16.4°C (195)	<u>V.d.:</u> 2.59 (195)

Toxicity:

Moderate (acute and chronic systemic) on inhalation (195).

Synthesis:

From action of ethyl alcohol on nitrous oxide gas; treat ethyl alcohol with alkali nitrites and sulfuric acid (190).

Ignition temperatures:

flash point: -31°F
ignition temperature: explodes at 194°F } (195)

Thermodynamic properties:

heat of combustion (at critical pressure): 334.21 cal (46)

UNSYMMETRICAL DIMETHYL HYDRAZINE

<u>Mol. Wt.:</u> 60.1 (195)	<u>Formula:</u> $(CH_3)_2NHNH_2$	<u>$\frac{n_D}{D_4}$</u> (46) 1.40753
<u>M.P.:</u> -58°C (195)	<u>Characteristics:</u> Liquid - ammoniacal odor (46)	<u>V.P.:</u> 15725 (195)
<u>d./sp. gr.:</u> .782 (195)	<u>B.P.:</u> 63.3°C (195)	<u>Viscosity:</u> .56 cps (at 68°F) (153)

Toxicity:

Not as toxic as hydrazine, stimulates central nervous system, threshold limit approximately .5 ppm (153).

Synthesis:

(1) react dimethylamine and chloramine; (2) react dimethylamine salt with sodium nitrate then reduce product; (3) catalytic oxidation of dimethylamine and ammonia (190).

Ignition temperature:

flash point: 34°F (195)
autoignition temperature: 145.9°F (127)

Solubility:

s. H_2O , ethanol, $(C_2H_5)_2O$ (46); completely miscible with H_2C , hydrazine, diethyl triamine, C_2H_5OH and most petroleum fuels (153).

Thermodynamic properties

critical temperature: 482°F
critical pressure: 786 psia
heat capacity (liq): 65 Btu/lb
coefficient of thermal expansion: .1 cp
heat of vaporization: 72 Btu/lb (at F.P.)
heat of combustion: 14,200 Btu/lb (75)

(1)

Military or industrial uses

Jet and rocket fuel component, used in chemical synthesis, used as a stabilizer in organic fuel peroxides (190)

Flammability

On a large surface may ignite due to slow air oxidation (153).

DIACETYLENE

<u>Mol. Wt.:</u> 50.1	<u>Formula:</u> $\text{HC}\equiv\text{CC}\equiv\text{CH}$	<u>Synonyms:</u> Butadiyne Butadiene
<u>M.P.:</u> -36.4°C (195)	<u>B.P.:</u> 10.3°C (195)	n_D^{20} 1.43862 (46)
<u>d./sp. gr.:</u> 2.233 (195)		

Toxicity

Moderate as acute systemic (195).

Unique conditions, reaction products

Spontaneously explodes with damp silver salts (195).

Flammability

Spontaneously flammable (27).

ACETYL PEROXIDE

<u>Mol. Wt.:</u> 118.1	<u>Formula:</u> $(\text{CH}_3\text{CO})_2\text{O}_2$	<u>Synonyms:</u> Ethanoyl peroxide Diacetyl peroxide
<u>M.P.:</u> 30°C (195)	<u>Characteristics:</u> Solid - crystal - colorless (195)	<u>B.P.:</u> 63.2°C (195)
<u>d./sp. gr.:</u> 1.18 (195)	<u>V.d.:</u> 4.07 (190)	

Toxicity

Moderate (acute local) as irritant, on ingestion, on inhalation (195).

Unique conditions, reaction products

Can cause ignition of organic materials on contact, produces heat on contact with water or steam (195).

Ignition temperatures

Above 122°F a violent decomposition may occur (142); flash point: 113°F (190)

Solubility

s. H₂O, alcohol, ether; d. NaOH, CCl₄ (190)

Handling

Keep from physical damage, no sources of ignition (electrical) to be located in the building, temperature range 32°F-90°F (142).

Military and industrial uses

Initiator and catalyst for resins (190)

Flammability

Spontaneously flammable if more than 24 hours old (195).

P-NITROSOPHENOL

Mol. Wt.:

123

Formula:

C₆H₄ONNO

M.P.:

144°C (46)

Characteristics

Solid - pale yellow
needles (46)

Synthesis

From phenol by action of cold nitrous acid (190)

Unique conditions, reaction products

Ignites with small amounts of acid or alkali (190)

Solubility

s. alcohol, ether, acetone; moderately s. H₂O (190)

Thermodynamic properties

heat of combustion: 715.5 cal (46)

Flammability

Impure - explodes by self-ignition (190)

PHENYLDIAZOSULFIDE

Mol. Wt.:

138.12

Formula:

C₆H₅NNSH

Characteristics

Solid - red (163)

Unique conditions, reaction products
Explodes when dried in air (153)

STYRENE OXIDE

Mol. Wt.:
120.15

Formula:
 C_8H_8O

Synonyms
Phenyloxiran
Benzene, 1,2epoxyethyl

d./sp. gr.:
1.0523₄¹⁶ (79)

Characteristics
Liquid (79)

B.P.:
381.6°F (129)

Ignition temperatures
flash point: 175°F
autoignition temperatures: 175°F } (129)

Solubility:
i. H_2O ; s. alcohol, ether (79)

2-ETHYLHEXALDEHYDE

Mol. Wt.:
128.21

Formula:
 $CH_3(CH_2)_3CH(C_2H_5)CHO$

Synonyms
2-ethyl hexanal

M.P.:
< -100°C (79)

Characteristics
Liquid (195)

V.P.:
1.820 (195)

d./sp. gr.:
.8205 (195)

B.P.:
163.760 (79)

V.d.:
4.42 (195)

Ignition temperatures
flash point (open cup): 125°F (195)

Solubility:
i. H_2O ; s. alcohol, ether (79)

Flammability:
Spontaneously flammable in air (217)

STEARIC ACID

Mol. Wt.:
284.49

Formula:
 $CH_3(CH_2)_{16}CO_2H$

Synonyms:
Octadecanoic acid

M.P.:
70.1°C (79)

Characteristics
Solid - monoclinic
leaf (79)

n_D³⁰
1.4299 (79)

d./sp. gr.:
.9408₂₀²⁰ (79)

B.P.:
183.5°C (79)

Unique conditions, reaction products
Heats spontaneously (129)

Ignition temperatures
flash point: 385°F
autoignition temperature: 743°F (129)

Solubility:
i. H₂O; ∞ alcohol, ether, acetone, C₆H₆; s. chloroform, CCl₄, CS₂ (79)

TRIDECYL ALDEHYDE

Mol. Wt.:
198.35

Formulas
CH₃·(CH₂)₁₁CHO

Synonyms
Tridecanal

M.P.:
14°C (46)

B.P.:
126-128¹⁰ (46)

$\frac{n_D^{18}}{D_4}$ (46)
1.4384

d./sp. gr.:
.8356₁₈¹⁸ (46)

Solubility:
i. H₂O; s. alcohol (79)

Flammability:
Spontaneously flammable in air (217)

DIAZIRINE

Unique conditions, reaction products
Explosive with air (10)

DIMETHYL DIMETHYL PHOSPHORAMIDATE

Characteristics
Liquid (127)

B.P.:
136°F (127)

Unique conditions, reaction products
s. nsitive to O₂ and moisture (127)

O, O DIMETHYL THIOPHOSPHORYL CHLORIDE

Characteristics
Liquid (127)

Unique conditions, reaction products

Unstable above 30-40°C, fumes, may explode at 100°C (127)

Ignition temperatures

autoignition temperature: 212°F (127)

3 PYRIDINE-DIAZONIUM FLUOROBORATE

Flammability

When completely dry - violent spontaneous decomposition (47)

PYRIDINIUM PERCHLORATE

Formula

$C_5H_5N \cdot HClO_4$

Synthesis

Formed during purification of pyridine with $HClO_4$ (113)

Flammability

Violent explosion in air (113).

VINYLMETHYL TETRAZOLE TRIBORANE

Unique conditions, reaction products

Spontaneous decomposition takes place at room temperature (5).

NOT REPRODUCIBLE

III. MISCELLANEOUS COMPOUNDS

Uranium Borohydride Decomposition Residue

Flammability:

Air reactive (197)

Aluminum and iodine
(equal weights)

Flammability:

Spontaneously inflames with H_2O (8)

Trimethyl Amine and Lithium Aluminum Hydride Addition Compound

Synthesis

Excess trimethyl amine reacts with an ethereal solution of $LiAlH_4$ in vacuo at $-37^\circ C$ to yield a white addition compound (163)

Solubility:

sl. s. ethane; i. C_6H_6 (163)

Flammability:

Spontaneously flammable in air (163)

Phenyl Derivative

Synthesis

A unstable white solid phenyl derivative is formed from the action of phenylmagnesium bromide on silver chloride or bromide in ether. The substance may be isolated but on evaporation of the solvent the dry solid decomposes in a puff of white smoke (184).

PSC-H Polymer

Synthesis

PSC-H at temperatures over $-124^\circ C$ forms extremely pyrophoric polymers (240).



Flammability:

With moisture spontaneous heating and ignition may occur (83).

Tributyl Borane and Dimethylchloride Reaction Products

Synthesis

Heat .14 moles tributyl borane with .31 moles dimethylchloride at $200^\circ C$ for 4 hours and $300^\circ C$ for 1 hour. Reaction yields low boiling gases and a pyrophoric mixture of products boiling between 20° and $100^\circ C$ (203)

SECRET

C_6H_5HgCl and $CrCl_3 \cdot 3THF$ Reaction Products

Synthesis

Heat $3C_6H_5HgCl + CrCl_3 \cdot 3THF$ at (1) Atmospheric pressure and temperatures greater than $60^\circ C$, (2) at room temperature and reduced pressure, then (3) wash red solid with diethyl ether to yield black pyrophoric, paramagnetic solid (244).

Unique conditions, reaction products

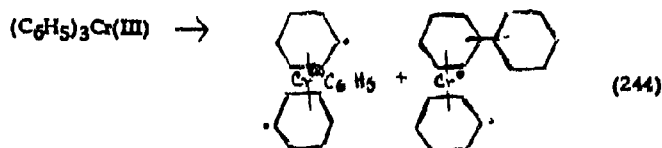
Hydrolysis of black powder yields bis-crane-complexes (244)

Flammability

Spontaneously flammable (244).

Structures

Black solid considered to be composed of approximately equal parts of bis-benzene- and benzene-biphenyl-chromium intermediates possible structure:



Difluorourea Decomposition Products

Unique conditions, reaction products

Difluorourea decomposition products in air are a possible cause of fire (6)

Uranium Borohydride and Trimethyl Boron Reaction Products

Synthesis

Uranium borohydride and trimethyl boron in a sealed tube at $60^\circ C$ for 4 hours yields a non volatile finely divided brown deposit (197).

Flammability

Vigorous reaction with air (197).

Aluminum Borohydride Decomposition Products

Synthesis

Evaporate aluminum borohydride rapidly at room temperature, a residue remains which contains Al, B, and active H_2 (196).

Flammability

Detonates spontaneously in air (196).

Magnesium Silicide and Acid (Usually Dilute HCl) Reaction Products

Flammability:

Spontaneously flammable (50).

Zinc and Iodine
(equal amounts)

Flammability:

Spontaneously flammable in H₂O (3).

Magnesium and Iodine
(equal amounts)

Flammability:

Spontaneously inflames with H₂O (3).

Resin

M.P.:

100-150°C (195)

Formulas:

80-90% abietic acid
5.6% anhydride

Synonyms:

Pine resin
Colophony
Gum resin

d./sp. gr.:

1.08²⁵ (195)

Characteristics:

Pale yellow to amber -
translucent fragments - turpentine odor and taste (195)

Synthesis:

Obtained as exudate, mixed with volatile oil, by incision of coniferous trees (distill off turpentine) (214).

Unique conditions, reaction products:

Can react with oxidizing materials (195).

Ignition temperature:

flash point: 370°F. (195)

Solubility:

s. alcohol, ether, C₆H₆, glacial acetic acid, many oils, and aqueous alkaline solutions; i. H₂O (190)

Military and industrial uses:

Forms soaps with aqueous alkali; dark products used in linoleum, rosin oil and dark varnishes, next series used in making size for paper; lighter grades in soap manufacture, used in resins of Pb, Co, etc., as a paint drier, sealing wax or plastic (190)

Flammability:

Spontaneously flammable in air (195).

Toxicity:

Slight as allergen (195).

Trimethyl Aluminum-Dimethyl Ether Complex

M.P.:

-29.9°C (226)

B.P.:

159°C (226).

Flammability:

Spontaneously flammable (226).

Hydrogen Phosphide and Impurities

Flammability:

Spontaneously flammable in air (62).

Oleum

Formulas:

H₂SO₄ with free SO₃

Synonyms:

Fuming sulfuric acid

Characteristics:

Liquid - viscous, colorless, or slightly colored (25)

Usual conditions, reaction products:

With moisture in air yields a white fog (25).

Military and industrial uses:

Used in World War I by Germans as a smoke screen, used by Germans in World War II in floating smoke pots (reacts with H₂O) (25). Sulfonating agent in production of organic compounds (214).

Titanium and Nitric Acid

Flammability:

Spontaneously flammable (74).

Bismuth Hydroxide and Aluminum Hydroxide

Synthesis:

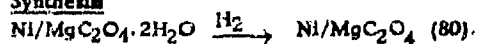
Bi(OH)₃ and Al(OH)₃ coprecipitated and reduced by H₂ at 170°-210°C is spontaneously flammable at ordinary temperatures (143).

Ni-Mg Mixed Oxalate Catalyst

Formulas:

Ni/MgC₂O₄

Synthesis



Flammability

Spontaneously flammable (80).

Aluminum Powder and Sodium Peroxide
(mixture)

Unique conditions, reaction products

Ignites with H_2O (3)

"FS" Solution of Sulfuric Trioxide in Chlorosulfonic Acid

Unique conditions, reaction products

Atomized in moist air, ingredients reacted with water vapor to form minute droplets of H_2SO_4 which appeared as a dense white cloud (26).

Military and industrial uses

Used as smoke screen in World War II (26).

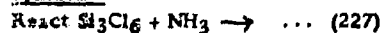
Sodium Peroxide and Sodium Thiosulfate
(mixture)

Unique conditions, reaction products

Ignites with H_2O (4).

$\text{Si}_2\text{Cl}_2 + \text{NH}_3$ Reaction products

Synthesis



Flammability

Spontaneously flammable (227)

Aluminum Iodide and Sodium Peroxide

Unique conditions, reaction products

Water-reactive smoke signal igniter (227)

Silane Gas

Unique conditions, reaction products

Aluminum chloride and calcium silicide reacts with H_2O to yield spontaneously flammable silane gas (227).

Nitroso Chloride of Alphamethylstyrene

Flammability

"Slow decomposition in air (in screw topped bottle) finally heat evolved or decomposition products accumulated to the point that the reaction was accelerated and sufficient pressure was built up to force the cap from the bottle, white smoke filled the room" (7).

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